THE
Perpetual Calculator:
OR,
TIME's
UNIVERSAL STANDARD.

In THREE PARTS.

I. A plain and eaſy Introduction to CHRONOLOGY ſince its laſt Improvement, containing an hiſtorical Account of the Old and New Stile, with plauſible Reaſons for changing the ſame. Rules for finding the Age and Change of the Moon, and whatever depends thereon, for ever.

II. An Account of the SOLAR SYSTEM, explaining the Laws and Means whereby the Planets are preſerved in their Orbits: The Cauſe of Eclipſes, and how to calculate them perpetually: A Synopſis of Comets, ſhewing how to predict the Appearance of four remarkable ones: A Synopſis of Aſtronomy, with Rules for diſcovering the Motions of the Celeſtial Bodies, how to acquire their Magnitudes, periodical Revolutions, diurnal Motions, Diſtances, &c. Invention of the Zodiac: Rules for the Equation of Time, &c.

III. PNEUMATICS and HYDROSTATICS, or the Science of Fluids diſplayed; containing the Doctrine of Tides, Generation of Meteors, and Changes of the Weather.

To which is annexed,

AN

APPENDIX,

CONTAINING,

Several uſeful ARTICLES relative to thoſe important Sciences.

Go, wond'rous creature! mount where ſcience guides,
Go, meaſure earth, weigh air, and ſtate the tides:
Inſtruct the planets in what orbs to run,
Correct old time, and regulate the ſun. POPE.

By R. WETHERALD, *Philomath.*

NEWCASTLE UPON TYNE:
Printed by I. THOMPSON and COMPANY. 1760.

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ARithmetic, vulgar and decimal, logrithmetical and algebraical; alſo merchant's accounts, according to the true Italian method; menſuration of ſuperficies and ſolids; gauging; geometry; trigonometry, plain and ſpherical; dialling; land ſurveying; geography; navigation; aſtronomy; conic ſections; the doctrine of fluxions; architecture; fortification; gunnery; optics and perſpective, in all their parts, according to the lateſt improvements, are carefully taught by the author, at his houſe in Great Salkeld, near Penrith, Cumberland: Where boarding may be had on eaſy terms.

BRITISH MUSEUM

DEDICATION.

To my Worthy SUBSCRIBERS,

Gentlemen,

I Think it an incumbent duty to return you my hearty thanks for your moſt favourable encouragement in this undertaking; tho' I am ſorry, on account of ſome unforeſeen accidents, I have not been able to publiſh it ſo ſoon as perhaps you might expect, which may have given ſome perſons too much reaſon to reflect on me, that I would never be able to bring it light, &c. But I hope the pains I have taken with the following ſheets will, in ſome meaſure, attone for the delay, and in part retrieve my character: So that, Phœnix like, I may riſe out of the aſhes of ridicule, wing my way through the ætherial regions, and give you an information of the motions of the celeſtial bodies.

As your generous ſubſcriptions and preſſing ſollicitations were the only motives which induced me to attempt a work of this kind; I therefore, as an additional favour, humbly beg leave to addreſs it to you, not doubting, but, under your protection, it will meet with a favourable reception from the public; and that it may merit your regard, and afford you ample ſatisfaction in the peruſal, is the moſt earneſt and hearty deſire of,

Gentlemen,

Your much obliged,

Humble Servant,

R. WETHERALD.

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THE

PREFACE.

AS *nothing can improve our underſtandings like Learning, the* MATHEMATICAL *kind ought moſt to be valued; for it extends itſelf to almoſt all arts, and is the unſhaken foundation of all ſcience; and when connected with Natural Philoſophy, it diſcovers to us the laws of the univerſe, tracing nature out of all her concealments, and repreſents to us the omnipotence and omniſcience of the great Creator of the univerſe, in the moſt ſtriking and wonderful manner.*

The doctrine of projectiles, and the whole art of gunnery, depends on this ſcience: Hence it may be deem'd the ſupport of our arms.

The ſtructure of forts, bulwarks, magnificent temples, houſes, and other edifices, owe all their ſtrength, beauty, and decorum to its rules.

And whatever ſtrikes the eye, or the ear, with beauty or pleaſure, from painting or muſic, muſt acknowledge this ſcience its parent.

I think I need not enumerate its ſervice in trade; and it would be unaccountable to recite all the advantages reſulting from this ſcience in the mechanical way. By our ſkill in this we make the very elements ſubſervient to us, and can employ their force to our advantage: We can paſs the trackleſs ocean, and ſafely arrive at the deſired haven.

As Chronology diſpoſes of time into certain portions or periods, its uſe in hiſtory will manifeſtly appear. It is alſo of immediate uſe in common occurrences, teaching how to find the golden numbers, epacts, dominical letters, age and change of the moon, moveable feaſts, &c. And will alſo ſerve as an introduction to aſtronomy, and therefore ought to be rightly underſtood before you proceed to the ſecond part.

In order to illuſtrate the lunar theory inſerted therein, page 46, it is obſervable, that between the 3d quarter and the change, the moon is frequently viſible in the forenoon, even when the ſun ſhines, and then ſhe affords us an opportunity of ſeeing a very agreeable appearance wherever we find a globular ſtone above the level of the eye, as ſuppoſe on the top of a gate: For if the ſun ſhines on the ſtone, and we place ourſelves ſo as the upper part of the ſtone may juſt ſeem to touch the point of the moon's lower horn, we ſhall then ſee the enlightened part of the ſtone exactly of the ſame ſhape with the moon, horned as ſhe is, and inclining the ſame way to the horizon. The reaſon is plain, for the ſun enlightens the ſtone the ſame way *as he does the moon, and both being globes when we put ourſelves into the above ſituation, the moon and ſtone have the ſame poſition to our eyes, and therefore we muſt ſee as much of the illuminated part of the one as of the other.*

In Aſtronomy I have given you a rationale of the Mundane ſyſtem, founded upon the Newtonian theory of gravity, and adapted to the capacities of ſuch as have not ſtudied the mathematics: Alſo an eaſy method of calculating the appearance of eclipſes; but one thing ought to be carefully remarked relating to thoſe phænomena, viz. the moon will ſometimes appear totally eclipſed when the ſun is above the horizon. Now this is occaſioned by the atmoſphere's refracting the ſun's rays, which makes him appear above the horizon when he is really below it; for the horizontal refraction being 34 minutes, 45 ſeconds, and the diameter of the ſun about 32 minutes, 15 ſeconds in breadth, when at his mean diſtance from the earth, the refraction cauſes both luminaries to appear above the horizon when they are below it.

At the zenith, refraction entirely vaniſhes, for which reaſon aſtronomers begin their day at noon, becauſe the increaſe and decreaſe of days terminated by the horizon are very unequal among themſelves, which inequality is likewiſe augmented by the inconſtancy of the horizontal refractions; and therefore the aſtronomer takes the meridian for the limit of diurnal revolutions, reckoning noon, that is, the very inſtant when the ſun's center is on the meridian, for the beginning of the day.

I have alſo given an eaſy method of predicting the appearance of 4 remarkable comets, from their periodical revolutions; but with regard to preciſeneſs, they often evade the niceſt calculations; for Dr Halley obſerves, that if comets were influenced by no other power but that of the ſun, there returns would be regular and in equal periods of time; but ſince the comets in their motion to and from the ſun muſt paſs by the orbits of the planets Jupiter and Saturn; whence they become liable to have their motions diſturbed, their celerities (in perihelio) altered, and conſequently the times of their periods, place of nodes, and inclinations of their orbits varied and rendered in ſome degree uncertain. Thus it happened with regard to the late comet, whoſe period was not quite 75 years, but at its return to the ſun in 1682, it came ſo near to Jupiter, and ſtaid ſo long in its neighbourhood, as to acquire an accelerated motion by the ſun and Jupiter, that it went off with greater celerity or ſwiftneſs than it came, and therefore went to a greater diſtance than before; conſequently its return was thereby made longer, which induced the doctor to believe it would probably not return till the end of the year 1758, or the beginning of 1759, at which time it preciſely appeared, and fixes the æra of perfection in this celeſtial ſcience.

The reader will likewiſe find what benefits accrue to mankind from both eclipſes and comets; nor have I omitted an account of the properties of planets: and tho' I could not dwell long on that ſubject, yet you may know from the table, p. 102, what kind of days, years, &c. their ſeveral inhabitants enjoy. There is alſo an account of the invention of the zodiac, and a table of the equation of time.

In part the 3d, the phænomena of tides are fully accounted for, with rules to find the times of full ſea ſeveral different ways; together with an account of the generation of winds, aſcent of vapours, &c. with philoſophical prognoſtications relating to the weather, and a great many other articles which will be found no leſs entertaing than uſeful; and that nothing may be wanting, I have annexed an Appendix, wherein is inſerted whatever eſcaped my notice in compiling the book.

The whole is laid down in as plain a manner as ſuch intricate ſubjects will admit of: And laſtly, I make bold to intimate to my readers, eſpecially ſuch as chuſe only to make uſe of the calculations, to obſerve the directions of the rules and tables carefully, and they will eaſily obtain their deſire, or meet with no difficulties but ſuch as they may eaſily ſurmount, relating to golden numbers, epacts, dominical letters, changes of the moon, eclipſes, &c. The curious will, I hope, find ample ſatisfaction in the more abſtruſe parts of theſe ſciences.

Some neceſſary REMARKS.

The circumferences of all circles, whether ſmall or great, are ſuppoſed to be divided into 360 equal parts called degrees, and each degree again into 60 equal parts called minutes, which minutes are again ſubdivided into 60 equal parts called ſeconds, and each ſecond into 60 equal parts called thirds, &c. The characters made uſe of to denote theſe ſeveral diviſions of the circle are as follow, viz. for degrees, a ſmall cypher is put over the ſignificant figure, thus, 36°, which denotes 36 degrees, for the minutes a ſmall daſh is uſed thus 24′, denoting 24 minutes, for the ſeconds two ſmall daſhes, thus, 5″, which are 5 ſeconds, and for the thirds, 3 daſhes, thus, 8‴, or 8 thirds, &c. for other parts. Hence the magnitude of any ſpherical arch is accounted by the number of deg. &c. it contains.

Note alſo, ☉ denotes the Sun. ☽ the Moon. ♄ Saturn. ♃ Jupiter. ♂ Mars. ♀ Venus. ☿ Mercury.

THE

Perpetual Calculator, &c.

PART I.

CHAPTER I.

The Uſe of the Luminaries. Aſtrology refuted. The Invention of the Year. An hiſtorical Account of the Old and New Stile, with Reaſons for changing the ſame, &c.

WE are informed by Moſes, when the divine author of the univerſe had created the two great luminaries of heaven, that he ordained them for ſigns, and for ſeaſons, and for days and years.

Now we have ſome inſtances in holy writ of their becoming ſigns; as the remarkable phænomena (of the ſaid luminaries) in Joſhua's days were ſigns to the Iſraelites, that their prophet was in great favour with the Lord; and even to their enemies that God aſſiſted Iſrael to avenge their cauſe; again, in the days of Hezekiah, the ſun became a ſure ſign, that the Lord would perform what he had promiſed that good king; and, if we reflect on the Egyptian darkneſs, inflicted by the hand of Moſes, (perhaps, it may not be thought quite foreign to this ſubject) when they were not permitted the light of either ſun or moon, for the ſpace of three days: Nor ought we ever to forget that gloomy ſcene, at the death of our bleſſed Saviour, which made the Jews confeſs their horrid vileneſs, by believing it a ſign from their offended God. And there are other ſigns of the ſun and moon foretold by our Saviour, which muſt be verified when his great wiſdom thinks moſt proper. Now, from what has been ſaid, we may infer that thoſe ſigns which have already happened were effected in a ſupernatural way, and which in no wiſe evince what the judicial aſtrologers have all along broached in the world, viz. that every (ordinary) configuration of the heavens indicates ſomething extraordinary to certain inhabitants of the earth; which muſt (in my opinion) be without foundation, otherwiſe it is limiting the providence of God to particular poſitions of the predominant planets, which occur and recur at ſtated periods of time; and is, in effect, denying him that prerogative aſcribed to his great name, which is vaſtly repugnant to the notions we ought to entertain of our Creator. Moreover, their chimerical ſcience is deemed inconſiſtent to reaſon by all people of learning and ſenſe, and therefore ought to be deſpiſed. But what keeps them ſtill in repute, among the credulous, is rightly obſerved by the author of the Turkiſh Spy: "Hence," ſays he, "it comes to paſs, that whereas one lie is apt to take away the reputation of any honeſt man, ſo that he ſhall not be believed when he ſpeaks true; on the contrary here, in our caſe, if an aſtrologer in his random predictions, by mere chance, hits upon a remarkable truth, it procures him credit for all the lies that ever he has or can be guilty of." Having been too prolix under this head, for which I beg the reader's pardon, I ſhall deſiſt, and proceed to the next, namely, to ſhew their uſes in the computation of time: but, before I proceed, it may not be amiſs to premiſe, that the phænomena of days and nights are occaſioned, by the revolution of the earth round its own axis, once in every twenty-four hours, called its diurnal rotation; and that of years, by the earth moving from any point of its orbit quite round the ſun, till it returns to the ſame point again, called its annual revolution; and from hence proceed the viciſſitudes of ſeaſons according to the poſition of the plain in which it moves, being inclined about 23 degrees and a half from the plain of the equator. Now, the earth moving in divers parts of its path, cauſes the ſun to appear in various parts of the heavens, namely, under different conſtellations, which the aſtronomers call ſigns: hence they define a year to be that ſpace of time which flows while the ſun is moving from any one point of the ecliptic, till he returns to the ſame point again; and the reaſon why it is adapted to the motion of the ſun rather than any other celeſtial object is, becauſe the ſeaſons are more conſpicuous by him than any of the reſt. But this annual ſpace of time being very difficult to aſcertain, the antients, who had but crude notions of it, made ſeveral attempts before they could determine, and tolerably adjuſt it to the ſun. Romulus, the firſt king of the Romans, imagined a year to conſiſt of ten months, or 304 days, from whence the laſt month of our year retains the name of December, as being the tenth of his. This year began on the firſt day of March, but it falling ſhort of the lunar year by 50 days, and of the ſolar year by 61, notwithſtanding their intercalations, this year became vague and unfixed.

Numa Pompilius, their ſecond king, perceiving Romulus's miſtake, corrected it, and added to it two months more, viz. January and February, and then it contained only 355 days, or 12 lunar months: his year began on the firſt of January, but in time, the form of this year was ſo corrupted by the indiſcretion of the pontiffs, in whoſe hands the power of intercalation was lodged, that the Winter months fell back to the Autumn, and thoſe of Autumn to the Summer. To remedy theſe inconveniences, the Emperor Julius Cæſar, who thought it a matter no way below his greateſt conſideration, adviſed with ſome Egyptian mathematicians about it (Soſigenes of Alexandria being the chief of them) by whoſe inſtructions he found that there were ten days more than Numa reckoned. The dictator, therefore, not only added to that year, in which he ſet about the reformation of the calendar, the common intercalation of 23 days, between the 23d and 24th days of February, purſuant to Numa Pompilius's inſtitution; but likewiſe 67 days more between November and December, ſo that this year contained 445 days.

This done, he inſtituted a civil ſolar year of 365 days and ſix hours: His common Year conſiſting of 365 days, and reſerving the ſix hours till every fourth year, they made another day, which was added before the 6th of the calends of March; ſo that in the fourth year they accounted the 6th of the calends of March twice, bis-ſexto calendas, whence came the word Biſſextile or Leap-year, as we call it, which hath 366 days; but in England, we add that intercalary day at the end of the ſaid month, every fourth year; and this account is called the Julian account, or Old Stile, and was uſed in our nation till the year 1752. Julius Cæſar having thus allotted 365 days and ſix hours to this revolution; but the Sun goeth about in leſs time, that is, (according to Sir Iſaac Newton's New Theory of the Moon) in 365 days, five hours, 48 minutes, 57 ſeconds, called a ſolar or tropical year; ſo that the emperor's year is above 11 minutes greater than the ſun's, which muſt of neceſſity cauſe a difference of ſo many minutes every year, betwixt the year which the ſun itſelf deſcribes in the Zodiac, and that which is reckoned upon in the calendar, which, though for a year or two, may paſs inſenſibly; yet, in the ſpace of 131 years, will amount to one whole day, that is, the beginning of the year in the calendar muſt be ſet one day back; as, for example, let the year begin at the vernal Equinox or Spring: In the Emperor Julius's time that fell out on the 24th of March, but of late, viz. at the reformation, it fell out upon the 10th of March, 13 days backwards, and ſomewhat more; and, if it had been let alone, would have gone back to the firſt of March, firſt of February, &c. till Eaſter would have fallen at Chriſtmas, and on all other ſeaſons in the year.

This difference in the account, ſome of the later Roman biſhops earneſtly endeavoured to reform; and the thing was brought to that perfection it now ſtandeth in (ſo much as it is) by Pope Gregory the 13th, in the year 1582. His mathematicians (whereof Aloyſus Lilius was the chief) adviſed him thus: That, conſidering there had been an agitation in the council of Nice (anno Domini 325) ſomewhat concerning this matter, upon the motion of that queſtion about the celebration of Eaſter; and, that the fathers of that aſſembly, after due deliberation with the aſtronomers of that time, had fixed the vernal Equinox at the 21ſt of March; and, conſidering alſo, that ſince that time a difference of 10 whole days had been paſt over in the calendar, that is, that the vernal Equinox or Spring, which began upon the 21ſt of March, had prevented ſo much as to begin in Gregory's days, about the 10th or 11th of the ſame, being ten days difference or thereabouts, they adviſed that ten days ſhould be cut off from the calendar, which was done, and ten days taken out of October of that year 1582, as being the month of that year in which that pope was born; ſo that when they came to the 5th of the month they reckoned the 15th; and ſo the Equinox was brought to its place again, and happened upon the 21ſt of March, as at the Nicene council; but that Lilius ſhould bring back the beginning of the year to the time of the Nicene council, and no farther, is to be marvelled at. He ſhould have brought it back to the Emperor Cæſar's own time, where the miſtake was firſt entered; and, inſtead of ten, cut off 13 days. Now in order to prevent the ſeaſons from going backward as before, he ordained that three intercalary days ſhould be omitted or dropped in every 400 years, by reckoning all thoſe years the date of which conſiſts of a number of entire hundreds not diviſible by 4, ſuch as 1700, 1800, 1900, 2100, &c. to be only common, and not biſſextile or leap-years, as they would otherwiſe have been, and conſequently omitting the intercalary days, which, according to the Julian account, would have been inſerted in the month of February in thoſe years; but at the ſame time he ordered that every four hundredth year, conſiſting of a number of entire hundreds diviſible by 4, ſuch as 1600, 2000, 2400, 2800, &c. ſhould ſtill be conſidered as biſſextile or leap-years, and conſequently that 1 day ſhould be intercalated as uſual in thoſe years. Hence we may obſerve, that the year 1700 was, according to this account, a common year, conſiſting of 365 days; whereas in the Julian account, it was leap year, and conſequently contained 366 days. This additional day added to the former correction rendered the Gregorian account 11 days before the Julian; and hence we ſee the reaſon why, in order to make the latter conformable to the former, they took 11 days out of September 1752: And this account is called the Gregorian or Lilian account, and with us the New Stile, it being preferable to the old or Julian account in theſe following particulars: Firſt, Time is, or may be by it reduced to its primitive form. Secondly, By it the ſeaſons are preſerved in their proper ſtations. And thirdly, The Gregorian year nearly correſponds with the aſtronomical year, even to a trifle: In all which reſpects, the Julian account is much leſs accurate; which are reaſons plauſible enough to induce our legiſlators to change the ſtile.

From the preceding part of this diſcourſe, it is plain that the Gregorian year conſiſts of 365 days, 5 hours, 49 minutes, and 12 ſeconds, which is only 15 ſeconds more than the true tropical year, and will not amount to one day in leſs than 5760 years.* As for example, the Gregorian account abates three days in 400 Julian years.—Now there are 146100 days in 400 Julian years, from which ſubtract 3, and the remainder is 146097, the days in 400 Gregorian years; which number 146097 being divided by 400, quotes 365 days; thus,

400)146097(365 days.

Remaind. 97
Which multiplied by 24 to reduce it into hours

Produces 2328 which divided by 400, quotes 5 hours; thus —— 400)2328(5 hours

Remaind. 328 which being reduced into minutes by multiplying it by 60

Produces 19680 which being again divided by 400; thus ——. 400)19680(49 minutes

Remaind. 80 which being alſo reduced into Seconds, by multiplying by 60

Produces 4800

Laſtly, 4800 ſeconds being divided by 400 as before, quotes 12 ſeconds.

Facit

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* Some make it 7200 years to acquire one day, for the 11 minutes in 400 years make 3 days, 1 hour, and 20 minutes: But the Pope neglected the 1 hour and 20 minutes, which in 18 times 400, or 7200 years, make out a whole day: But as the exceſs is 3 ſeconds above 11 minutes, it muſt be erroneous.

	days.	hours.	min.	ſec.
Facit	365	5	49	12
From which take	365	5	48	57
Remainder	0	0	0	15 Seconds, as above.

Then 5760
multiplied by 15

Produces 86400 ſeconds, which brought into hours by dividing by 60 thus, 60)86400

60)1440 quotient.

24 the laſt quotient, being 24 hours, or one day, which plainly illuſtrates the above relation: And therefore no leſs than a cycle of 5760 years will reſtore the firſt agreement between the calendar and the ſolar motions. But tho' the year is now fixed, and the ſame as at the Nicene council, it is certain that from the Julian reformation to that council, the year had anticipated 2 days, 20 hours, 8 minutes, and 30 ſeconds; and therefore we are ſo much later now in our account than at the Julian reformation, which was occaſioned through Lilius's inadvertency as was hinted before.

This method of computing time being for its exactneſs preferable to any other, is not without its defects: (and perhaps, as Tycho Brache and Caſſini imagine, it is impoſſible ever to bring the thing to a perfect juſtneſs) For firſt, the Gregorian intercalation does not hinder but that the equinox ſometimes lags behind the 21ſt of March as far as the 23d; and ſometimes anticipates it, falling on the 19th: And the full moon which falls on the 20th of March is ſometimes the paſchal; and yet not ſo accounted by the Gregorians; on the other hand the Gregorians account the full moon of the 22d of March, the paſchal; which yet falling before the equinox is not the paſchal. In the firſt caſe therefore, Eaſter is celebrated in an irregular month; in the latter, there are two Eaſters in the ſame eccleſiaſtical year. In like manner, the cyclical computation being founded on the mean full moons, which yet may precede or follow the true ones by ſome hours, the paſchal full moon may fall on a Saturday, which is yet referred by the cycle to Sunday; whence, in the firſt caſe, Eaſter is celebrated eight days later than it ſhould be; in the other, it is celebrated on the very day of the full moon, with the Jews and Quartodeciman heretics, contrary to the decree of the council of Nice. But theſe irregularities (which but rarely happen) being inconſiderable in reſpect to what might be advanced in the Julian method of computing time, which renders this account ſtill preferable to the Julian or Old Stile: This occaſioned moſt foreign ſtates to receive it ever ſince the reforming of the calendar; and by act of parliament paſſed in the 25th year of his preſent majeſty's reign, viz. 1751, it commenced in all the dominions under the crown of G. Britain in the year following, ordering that the natural day following the 2d of Sept. ſhould be accounted the 14th, omitting the intermediate 11 days of the common calendar; ſince which time Sweden, Denmark, and other European countries, who computed time by the Julian account, have followed this example.

I ſhall now proceed to other ſpaces of time which bear the denomination of years among the aſtronomers; ſuch as the lunar year, in which ſpace of time the moon performs 12 compleat revolutions about the earth, called lunations, and contains 354 days, 8 hours, 48 minutes, 38 ſeconds, and 12 thirds: And there is alſo another kind of ſolar year, beſides the tropical year abovementioned, called a ſydereal year, which is the ſpace of time in which the ſun departing from any fix'd ſtar, comes to it again, and contains 365 days, 6 hours, 9 minutes, and 14 ſeconds; but this being not quite ſo exact as the other by reaſon of the ſtars apparent ſhifting from their places, which is occaſioned by the proceſſion of the terreſtrial equinoxes, the tropical year, which depends on one of the cardinal points, viz. the equinox or ſolſtice, gains preheminence. The aſtronomers have alſo different ſorts of months; the firſt, which is alſo the natural one, is properly a lunar month, or the ſpace of time in which the moon runs through the zodiac; and is either (1) Synodical, called a lunation, which is the time contained between the moons parting from the ſun at the conjunction (or change) and returning to him again, which is 29 days, 12 hours, 44 minutes, 3 ſeconds, and 11 thirds. (2.) Periodical, which is the ſpace of time wherein the moon makes one compleat revolution, or returns to the ſame point in the zodiac whence ſhe departed; this contains 27 days, 7 hours, 43 minutes, and 8 ſeconds: (3.) The Illuminative month is the time between the appearance of two new moons next each other, or the time a moon is obſerved to ſhine, which is always variable. The ſecond ſort is the ſolar month, which is improperly thus called, as being only the ſpace of time in which the ſun runs through one ſign of the zodiac; which months, one with another, contain each 30 days, 10 hours, 29 minutes, 5 ſeconds. The third are civil months, and are thoſe which are framed to ſerve the uſes of civil life, and are different in different nations and countries of the world. Theſe come very near the quantity of aſtronomical months, both lunar and ſolar; whence came the diſtinction of civil lunar and civil ſolar months. A civil lunar month conſiſteth alternately of 29 and 30 days through the year. Thoſe of 29 days were called cavi or hollow; and thoſe of 30, pleni or full. Civil ſolar months conſiſted alternately of 30 and 31 days, except one of the 12, which every 4th year was to have 30 days, in other years 29 only.

The names, length, &c. of the civil months, uſed by ſeveral nations to compoſe their years or calendars, may be ſeen from the following Table.

TABLE of the NAMES, &c. of the CIVIL MONTHS uſed by ſeveral Nations.

No	*Julian Year.*	Days	*Ancient Roman Year.*	Days	*Ancient Grecian Year.*	Days
1	January	31	Januarius	29	Hecatombæon	29
2	February	28	Februarius	28	Metagitnion	30
3	March	31	Martius	31	Bœdromion	29
4	April	30	Aprilis	29	Mæmacterion	30
5	May	31	Maius	31	Pyanepſion	29
6	June	30	Junius	29	Poſideon	30
7	July	31	Quintilis	31	Gamelion	29
8	Auguſt	31	Sextilis	29	Antheſterion	30
9	September	30	September	29	Elaphebolion	29
10	October	31	October	31	Munychion	30
11	November	30	November	29	Thargelion	29
12	December	31	December	29	Scirrhophorion	30
	Days in the year	365	Days in the year	355	Days in the year	354
	This is a ſolar year, and there remains 5 hours and 49 minutes towards an intercalary day for biſſextile or leap-year.		This was the year which firſt began with Martius, till Numa added two more months, Jan. and Feb. and after Julius Cæſar added ten days to equate it with the ſolar year.		This is a lunar year uſed at Athens, and required 11 days 5 hours, and 49 minutes to equate it with the ſolar year.	

No	*The Jewiſh Civil Year.*	Days	*The Syrian Year.*	Days	*Arabic and Turkiſh Year.*	Days
1	Tiſri	30	Tiſhrin I.	31	Muharram	30
2	Marcheſhvan	29	Tiſhrin II.	30	Saphar	29
3	Caſlev	30	Canun I.	31	Rabia I.	30
4	Thebet	29	Canun II.	31	Rabia II.	29
5	Shebat	30	Shabat	28	Jomada I.	30
6	Adar	29	Adar	31	Jomada II.	29
7	Niſan	30	Niſan	30	Rajab	30
8	Jiar	29	Aiyar	31	Shaaban	29
9	Sivan	30	Haziram	30	Ramadan	30
10	Tamuz	29	Tamuz	31	Shawal	29
11	Ab	30	Ab	31	Dulkaadah	30
12	Elul	29	Elul	30	Dulheggia	29
	Days in the year	354	Days in the year	365	Days in the year	354
	In the embolimic year after Adar they add the month Veadar of 30 days.		This is equal to our Julian year.		This year is lunar, and the ſame with the Grecian and Jewiſh year.	

The

The TABLE continued.

Nº	*Perſian Year.*	Days	*Egyptian Year.*	Days	*Ethiopian Year.*	Days
1	Afrudiah Meh	30	Thoth	30	Maſcaran	30
2	Ardihaſcht Meh	30	Paophi	30	Tykymt	30
3	Cardi Meh	30	Athar	30	Hydar	30
4	Thir Meh	30	Chojac	30	Tyſhas	30
5	Merded Meh	30	Tybi	30	Tyr	30
6	Schabarir Meh	30	Mechir	30	Jacatit	30
7	Mehar Meh	30	Phamenoth	30	Magabit	30
8	Aben Meh	30	Pharmuthi	30	Mijazia	30
9	Adar Meh	30	Pachon	30	Ginbat	30
10	Di Meh	30	Pauni	30	Syne	30
11	Behen Meh	30	Ephiphi	30	Hamle	30
12	Affirer Meh	30	Meſori	30	Nahaſe	30
Emboliſm	Muſteraka	5	Epagomenæ	5	Pagomen	5
	Days in the year	365	Days in the year	365	Days in the year	365

Some REMARKS on theſe Civil Years.

The Greeks counted their year by the motion of both ſun and moon, and finding there was 11 days difference between the lunar and ſolar year, at firſt they added an intercalary month every two years, containing 22 days, which they called the added or inſerted month: Afterwards, conſidering the 6 hours alſo, they put their emboliſm off till 4 years end, and then making the three firſt years to contain 354 days a piece (which is the lunar year) this made the 4th year to have 399 days. And to make this intercalation the more remarkable, they inſtituted the olympic games on every ſuch 4th year; whence came the computation by olympiads, each of which contained 4 years.

The Jews had their ſecular year, which began at the autumnal equinox, and their ſacred year which began at the vernal one.

The Egyptians, Chaldeans, and Aſſyrians, firſt meaſured the year by the courſe of the ſun, which they ſuppoſed to contain 360 days; afterwards they added 5 more, but yet no notice was taken of the 6 hours; by which means the Egyptian year hath fixed no place in reference to the true ſolar year; but anticipating a day every four years, runs quite round in 1460 years.

This way of reckoning continued till Egypt becoming a province of the Roman empire, they took the Julian account, only they kept the names of their months ſtill, and ordered the matter ſo, that their Thot, the 1ſt day of the year, always happened on the 29th of Auguſt in the Julian year. So that the Egyptian or Coptic year is 4 months and 3 days before the Roman year, which begins with the calends of January.——The Perſians account (according to the Egyptian way) 365 days.——The Arabs, Saracens, and Turks, count their year by the motion of the moon, and make it conſiſt of 12 moons or months, whereof ſome have 30 and ſome 29 days alternately; and theſe altogether make but 354 days; ſo that their month Muharram, in which they place the beginning of the year, in leſs than 34 years will run quite round, and be in all the ſeaſons. This kind of year is now uſed by the Turks, and ſeems to have had its riſe in countries where the difference between ſummer and winter is not ſo ſenſible as it is with us; and where for want of aſtronomy, they knew not how to eſtimate the ſolar year, and therefore began their account of months from the phaſes of the moon: And hence, as the learned aſtronomer Dr Gregory hints, it came to paſs that they began their account of the civil day at ſun-ſet; for their day muſt begin when their month and year did, and that was with the new moon, which being to be determined by view, could not be diſcovered till after ſun-ſet. The Arabs indeed, by a cycle of 30 years, remedy the above diſorder, by means of an intercalation or emboliſm of 11 days. The Athenians began their year at the new moon after the ſummer ſolſtice in their month Hecatombæon, as Plutarch ſays.

There were alſo ſome nations who made their year to conſiſt only of 4, or of but 3 months, as Macrobius tells us in his Saturnalia, lib. I. The Carians and Acharnanians, ſaith Juſtin, made their year to conſiſt of ſix months, and reckoned but 15 days to their month.

A month is divided into four parts, which we call weeks, and each week is again made to conſiſt of ſeven parts called days of theſe months: There are 13 in a Julian year, and one day over; of weeks, there are 52; and of days, 365, as before obſerved.

A day is either the ſpace of time contained between the moments of the ſun's riſing and ſetting, or which makes one entire revolution. The firſt is called an artificial day, the latter a natural day, and by the Greeks Nychthemeron, becauſe it included night and artificial day together. The artificial day is ever variable and unequal, for the ſun's courſe being always oblique to the horizon, and always varying, cauſeth the time of his ſtay, or his duration above the horizon, which is the artificial day, to be ever variable and changing, and that in reality for one half of the year, or the time the ſun is paſſing from one ſolſtice to the other, increaſing or decreaſing.—The natural day is either aſtronomical or civil: The aſtronomical day is the time which flows between the ſun's leaving any meridian and its return to the ſame; that is, the ſpace of time in which the earth makes one revolution about its axis, which is 23 hours, 56 minutes, 4 ſeconds, and the time anſwering to the degrees it hath deſcribed in its annual orb during that revolution. Now this additional motion is always unequal, both becauſe of the obliquity of the plane of the ecliptic to the plane of the equator, and alſo becauſe of the oval figure of the earth's motion; but one time with another it is 59 min. 8 ſec. per day, which is perform'd in 3 min. 0 ſec. and 32 thirds: Therefore a mean aſtronomical day conſiſts of 23 hours, 59 min. 4 ſec. and 32 thirds.—The civil natural day is that which is meaſured out by the equable motion of machines, as clocks, watches, and other automata; this is always equal, and contains 24 hours.

The beginning of this natural civil day is various, according to the different uſage of people. The antient Greeks, Jews, Bohemians, Sileſians, with the modern Italians, and Chineſe, commence the civil day at ſun-ſet. The antient Babylonians, Perſians, Syrians, with the modern Grecians, &c. begin their day from ſun-riſe. The Auſonians, Egyptians, Romans, with the modern Engliſh, French, Dutch, Germans, Spaniards, and Portugueze, at midnight. And laſtly, the Umbrians, and Arabians, with the modern aſtronomers, begin their day at noon. But in this affair you meet with ſome uncertainty, in what relates to antiquity.

An hour is the 24th part of a day, and is equal or unequal. Equal

hours

hours are thoſe by which the whole time of a civil natural day and night is divided into 24 equal parts. Unequal hours are thoſe by which the time of an artificial day is divided into 12 parts, and the night into as many. The hours of an aſtronomical day, or thoſe from noon to noon, are not preciſely equal, but the difference is ſo ſmall that it is not worth minding, and makes no error in uſes of common life.

The hours are denominated of the people who uſe them: Thus Babylonian hours commence their order from ſun-riſing; Italian hours from ſun-ſetting; aſtronomical hours from noon or mid-day: And by ſome the unequal hours are ſtiled Jewiſh, becauſe that nation uſed them.—— Unequal hours may be reduced to equal ones by the Rule of Three; thus, As 12 hours, is to the ſpace of an artificial day, ſo is 1 equal hour to its correſpondent unequal one.

An hour is divided into 60 equal parts called minutes or ſcruples, and each minute into 60 ſeconds; theſe again into 60 thirds, and ſo on: Theſe diviſions are well enough known. But the Jews, Chaldeans, Arabians, and other eaſtern people, divide the hour into 1080 ſcruples, becauſe there is no number capable of ſo many diviſors as this, which thereſore they thought moſt fit for uſe. But the number 1080 is 18 times 60, and ſo one minute contains 18 Jewiſh ſcruples.

The larger ſpaces of time which have found diſtinction among mankind are, (1.) A luſtrum, which is a certain ſpace of time antiently applied to civil uſes, as ſacrificing, taxations, letting farms, &c. and though formerly it was reckoned to conſiſt of 5 years, yet chronologers do now repute it only as 4. (2.) Seculum, a century or ſpace of 100 years, tho' among the antients they had a natural ſeculum, which they reputed to be the longeſt ſpace of a man's life. (3.) Ævum, an age, a ſpace of time indefinitely uſed for the life or age of a man; ſometimes for 100 years, and ſometimes for eternity. (4.) The Olympiad, which was a ſpace of 4 years, or 50 months of 30 days each. At the expiration of each olympiad the olympic games were celebrated near the city Olympia, in honour of Jupiter Olympius. Tho' they did not celebrate their games till the fifth year, yet an olympiad conſiſted only of four Julian years and the odd biſſextile day, as was before remarked.

For Dr Halley obſerved inhis ſynopſis of the aſtronomy of comets, that they commenced on Auguſtus Cæſar's birth day, which was on the 23d of Sept. and continued 7 days; and this he gathered from a fragment of an old Roman calendar, in page 135, of Gruter, the new edition. Now they began their year at the new moon after the ſummer ſolſtice, which was about the 11th day of June according to the Julian form.

CHAP. II.

Shewing the Uſes of Cycles and Periods.

IT is to chronology, as Mr Locke well obſerves, that hiſtory owes its uſe and beauty, as being without it a mere chaos, a jumble of facts heaped together, and conſequently capable of affording neither pleaſure nor inſtruction; hence periods and epochas become pillars whereon the whole fabric of hiſtory is founded. I ſhall thereſore proceed to their uſe.

DEFINITION.—A period or cycle is (in plain Engliſh) a circle of years, months, days, &c. or it is a perpetual round or circulation of any the ſame parts of time ; ſo that the laſt continually returns upon and ſucceeds the firſt. Of cycles, the following are of famous and frequent uſe.

The cycle of the ſun or ſolar cycle, is a circle or revolution of 28 years, which contains all the poſſible combinations of the dominical letters, in reſpect to their ſucceſſive order, as pointing out the common years and leap-years ; ſo that after the expiration of the cycle, the days of the month return in the ſame order to the ſame days of the week thro' the next cycle ; except that upon every centeſimal year, which is not a leap-year, the letters muſt be removed one place forward to make them anſwer to the years of the cycle : For inſtance, if the year 1800 was a leap-year, as every centeſimal year is in the Julian account, the dominical letter would be E D, and C would be the dominical letter of the next year ; but as it is a common year in the Gregorian account, D is the dominical letter of 1801, which anſwers to the 18th of the cycle, C to the 19th, &c. until the next centeſimal year. To find the year of this cycle for any year of the chriſtian æra, add 9 to the current year of Chriſt, becauſe the cycle commenced 9 years before the chriſtian æra, and divide the ſum by 28, the quotient will ſhew the number of cycles, which have revolved ſince the beginning of that in which the chriſtian æra commenced, and the remainder, if any, ſhews the current year of the cycle ; but, if there be no remainder, it ſhews that it is the laſt or 28th year of the cycle. This cycle received both its name and origin from the ſeven letters of the alphabet A, B, C, D, E, F, G, which were placed in the almanack to denote the days of the week in order, from the firſt to the ſeventh throughout the year. I ſhall only annex the following table, and ſo deſiſt, deferring the remaining part till I ſhew how to find the dominical leter for ever.

The dominical letter of each year, in this cycle, until the year 1800, appears by the following table :

1 DC	5 FE	9 AG	13 CB	17 ED	21 GF	25 BA
2 B	6 D	10 F	14 A	18 C	22 E	26 G
3 A	7 C	11 E	15 G	19 B	23 D	27 F
4 G	8 B	12 D	16 F	20 A	24 C	28 E

The Metonic period, or cycle of the Moon, is next in conſequence and importance ; perhaps, it may not be improper to give ſome account of its invention. It was obſerved among the remarks of civil years, the Greeks made their three firſt years to conſiſt only of 354 days a-piece, which were only Lunars ; then they made an intercalation or emboliſm of 45 days on every 4th year, to make them accord with four ſolar years ; but they found that this would not do in proceſs of time, and therefore they firſt reduced the intercalation to 8, and then to 11 years ; but ſtill there was great confuſion till one Meton or Meto, a citizen and famous aſtronomer of Athens, joined the two laſt periods 8 and 11 together ; which done, he made a period of 19 years, in which the two motions of the ſun and moon are wholly accommodated, and the moon changes on the ſame day of the month that ſhe did 19 years before. He firſt publiſhed it at Athens in the year before Chriſt, 432. This diſcovery, for its fullneſs, was much celebrated, and the number of the period 19 the Athenians ordered to be ſet up in a public place, and to be written in characters of gold ; whence it took the name it ſtill retains, being called the Golden Number, and ſometimes it is called the Prime ; but the author called it Enneadecaëteris, or Cycle of 19 years, which we ſince call the Lunar Cycle, or Cycle of the Moon, as above. I ſhall treat more fully of this head when I direct how to find the golden number.

N. B. Tho' the Moon changed on the ſame day of the month that ſhe did 19 years before, ſhe fell ſhort of the preciſe time by 1 hour, 27 minutes, and 33 ſeconds, which was not yet perceived.

From the cycles of the Sun and Moon, multiplied into one another, ariſes another cycle or period of 532 years (for 28 multiplied by 19 gives 532) which was invented by Victorius, a preſbyter of Limoges in Aquitain, by order of Hilary, biſhop of Rome, and is, therefore, called the Victorian Period; after the expiration of which, he ſuppoſed all the new and full moons, the ſame time of Eaſter, and the ſame dominical letters, would all come over again in the ſame order of time as in the former cycle, and ſo on in all the following cycles for ever. This was finiſhed and firſt publiſhed in the year of our Lord 457: Dionyſius Exiguus, a Roman abbot, corrected it in ſome particulars, and it was called the Dionyſian Period from him; as alſo the great paſchal, becauſe the weſtern churches went by it for many ages, till Pope Gregory XIII, new modelled it, as before related.

To find the year of the Dionyſian period, for any given year of Chriſt, to the current year, add 457, and divide the ſum by 532, what remains is the year of the period ſought. Example: to the year 1758 add 457, the ſum is 2215, which divided by 532, the quotient is 4, which ſhews it has made 4 revolutions, and 87 the remainder, is the current year of the Dionyſian period.

N. B. This period is alſo called the Luniſolar year, and ſometimes the Cycle of Eaſter.

There is another period of 76 years invented by Calippus Cyzicenus of Myſia, 331 years before Chriſt, and therefore called the Calippic Period. He ſuppoſed the exceſs of the Solar year above the Lunar, at the end of the Metonic cycle of 19 years, would, in the courſe of four of thoſe cycles, or 76 years, amount to a whole day, and ſo caſt away a day in every period of 76 years. But herein he was greatly deceived, for the exceſs of the Julian above the Lunar year, in one cycle, is ſcarce an hour and a half; but ſuppoſing it 1½ hour, in 4 cycles or 76 years, the amount would be only 6 hours inſtead of 24: wherefore the error of this period is a deficiency of 18 hours and ſomewhat more.

This gave occaſion afterwards to Hipparchus, of Nicæa in Bithynia, to make a new correction of the Metonic cycle; for he obſerving that the Calippic period was laid too great by a quarter of a day, in the ſolar motions, he multiplied it by 4, which produced a new period of 304 years; and therefore, in every 304 Julian years, he deducted a whole day that the Moon might come again to the old place in the calendar; and this was very near the truth, and much the ſame with the Gregorian correction, or New Stile, made many ages after.

N. B. Hipparchus was alſo too ſhort in his computation, for his period terminated 8 years and a half ſooner than it ought to have done, as will be ſhewn farther on.

The Romans made uſe of a cycle, called the Cycle of Indiction, which had no relation to the celeſtial motions, but was uſed for civil purpoſes, the chief of which was to indicate or make known the time of certain payments made by the Roman ſubjects to the republic; it conſiſted of 3 luſtrums, or 15 years, and was eſtabliſhed by Conſtantine, A. D. 312, in the room of the Greek olympiads. To find the year of this cycle, ſubſtract 312 from the given year of Chriſt, and divide the remainder by 15, and neglecting the quotient, (which only ſhews how many revolutions it has made ſince it firſt commenced) what remains, is the year of indiction ſought.

From the multiplication of the cycles of the Sun, Moon, and indiction, ariſes the famous period called the Julian period, from Julius Scaliger, the reputed author thereof (tho' ſome call him Joſeph, and ſay it acquired that name, becauſe he made uſe of Julian years in his computations:) this period conſiſts of 7980 years (for 28 by 19 gives 532, and that by 15 gives 7980). This period had its beginning fixed to the 764 year before the creation, and is not yet compleated, and therefore comprehends all other cycles, periods and epochas, and the times of all memorable actions and hiſtories.

There is but one year, in the whole period, that has the ſame numbers for the three cycles, of which it is made up; and therefore, if hiſtorians had remarked in their annals the years of their reſpective cycles, there had been no diſpute about the time of any action.

The firſt year of Chriſt was the 4714th year of the Julian period; and therefore, if to the current year of Chriſt we add 4713, the ſum will be the year of the Julian period.

So the year 1758 will be found to be 6471ſt year of the ſaid period. Alſo, if, from the given year of the Julian period, you ſubſtract 4713, the remainder is the year of the chriſtian æra. Thus, if it was required to know what year of Chriſt correſponded to the 6471ſt of the Julian period, it will be found to be 1758: and you may know what are the golden numbers, cycles of the Sun, and indiction in any year of this period; for, as the firſt year of this period is the firſt year of every cycle in it, ſo the rule is to divide the given year of the Julian period by 15, 19 and 28, ſeverally, and the reſpective quotients will ſhew the number of cycles elapſed from the beginning; and the remainders will be the years of the ſeveral cycles correſponding to the ſuppoſed year of the period. Thus, if it was required to find the characters of the three cycles for the 6471ſt of this period, divide 6471, the given year of the Julian period by 15, the cycle of indiction, the quotient 431 gives the number of rounds of the cycle of indiction that have elapſed from the beginning of the period, and the remainder 6 is the preſent year of the ſaid cycle. In like manner, if you divide by 19, the quotient 340 will expreſs the number of rounds of the lunar cycle, and 11 the remainder will be the golden number. By the ſame method of proceeding, if you divide by 28, the cycle of the Sun, the quotient 231 gives the number of rounds of the ſolar cycle, and the remainder 3 is the preſent year of the ſaid cycle.

Scaliger, when he firſt invented this period, might eaſily have accommodated its years to the years of the world; he had only to apply its firſt year to the year of the creation, and then computing the cycles downward, ſhew what years of theſe cycles correſponded to the year when he introduced it. But ſuch a method would have had this inconvenience attending it, that the cycles of this period would not have been the ſame with the cycles then in uſe. He, therefore, thought it better to take the cycles as he then found them ſettled in the calendar of the Latin church, and, tracing them backward through their ſeveral combinations to the year in which they all began together, there fixed the beginning of his computation, which was, by this means, carried up ſeveral hundred years beyond the creation of the world. Now this method is not only beſt ſuited to practice and common uſe, as the cycles of this period are the ſame with thoſe of the calendar, but it has alſo this advantage, that thereby we can with greater eaſe adjuſt the different opinions of chronologers. For almoſt all of them proceeding upon different ſyſtems, and varying their account of the years between the creation and the birth of Chriſt, it ſo happens that moſt of theſe computations, eſpecially ſuch as are in uſe among the weſtern chriſtians, fall within the years of the Julian period; ſo that by reducing them to it, (as ſhall be ſhewn immediately) we may obtain an eaſy way of comparing them together, and adjuſting them one to another.

I have already taught how to find the year of this period correſponding to the given year of Chriſt, and the year of any epocha preceding our Saviour's birth, may be found in this period, by knowing the year before Chriſt, in which the epocha begins; if you ſubſtract that from 4714, the remainder will be the year of the Julian period, correſponding with the firſt of the ſaid epocha: and having once connected the beginning of the epocha, it will be eaſy to connect its ſubſequent years, as there is nothing more required but the addition of theſe years. To illuſtrate this matter, by example, the Olympiads began in the 776th year before Chriſt, which, ſubſtracted from 4714, leaves 3938 for the year of the Julian period. But the year of the Julian period may be had from the characters of any given year, either before or after the birth of our Lord, by common multiplicators thus: there muſt be ſuch a number found, that being multiplied by the product of 19 by 15, as that product, when divided by 28, the remainder will be 1. This number will be 17, then 19 multiplied by 15 gives 285, which multiplied by 17 produces 4845, the common multiplicator. Secondly, we muſt find a number, which being multiplied by the product of 28 by 15, and that product divided by 19, leaves for the remainder 1, and this number is 10; for 28 by 15 gives 420, which multiplied by 10 gives 4200, the common multiplicator. Thirdly, we muſt find a number, that being multiplied by the product of 28 by 19, and that product divided by 15, leaves 1. This number is 13; then 28 by 19 gives 532, and that by 13 gives 6916, the multiplicator ſought. Then to find the year of the Julian period, for any given year, this is the rule:

Multiply the fixed number $\left\{\begin{array}{c}4845\\4200\\6916\end{array}\right\}$ by the cycle of the $\left\{\begin{array}{l}\text{Sun,}\\\text{Moon,}\\\text{Indiction,}\end{array}\right.$ the ſum of theſe products divided by 7980, the remainder is the year of the Julian period to any given year.

EXAMPLE.

The year in which our Lord was born was the 10th of the ſolar cycle, the 2d of the lunar, and the 4th of indiction; in order to this, according to the foregoing inſtructions, I multiply 10, the character of the ſolar cycle, into 4845, and the product thence ariſing is 48450; again, I multiply 2, the lunar cycle, into 4200, and find the product to be 8400; laſtly, I multiply 4, the year of indiction, into 6916, and obtain 27664 for the product. All theſe products added together make 84514, and this ſum divided by 7980 gives 10 for the quotient, which is not to be regarded, with a remainder of 4714, which expreſſes the year of the Julian period; ſo that 4714 is the year thereof, anſwering the year of Chriſt's nativity. I have been prolix under this head, becauſe it is eſteemed the ſtandard of all computations now in uſe, to which they may be reduced, and by which they may be regulated.

There is another, called the Conſtantinopolitan Period, which is of the ſame length or number of years as the Julian period, viz. 7980; but it neither begins at the ſame time, nor have the cycles of the Sun and Moon the ſame ſituation in both: for the firſt year of the ſolar cycle, in the Julian, is the 12th in this; and the firſt of the lunar, is the 17th here; the cycle of indiction is the ſame, for the moſt part, in both. This period is uſed by the Greeks, as the Julian is by the Latins, or Roman hiſtorians.

C H A P. III.

Of Æras or Epochas, and their Uſe; with Remarks concerning them.

GREAT diſputes have ariſen among the etymologiſts about the derivation of the word Æra, but what ſeems moſt probable, it is thought to ariſe from theſe initial letters A. E. R. A. which among the Spaniards, who began their æra from the reign of Auguſtus, ſtood for Annus erat regni Auguſti; for æra or epocha import a certain term or fixed point of time, made famous by ſome memorable accident, from which, as from a root, we make our calculations and computation of time; and all remarkable actions are diſpoſed and recorded according to the ſeries of years which follow from ſuch a root or epocha. The principal æras are thoſe of the creation, of the Olympiads among the Greeks, of the building of Rome, that of Nabonaſſar, the death of Alexander, the Abyſſine æra of the martyrs, the Arabian Hegira, the Perſian Jeſdegird, the moſt famous æra of the birth of Chriſt, and that which contains them all, the Julian period above explained. All theſe epochas and æras together, with ſeveral others of leſs note, have, in the following table, their beginnings reduced or fixed to the years of the Julian period, the creation of the world, and to the years before and after Chriſt.

		Jul. P.	A. M.	A.C.
1	The creation of the world, after the Jews	952	1	3760
2	The common epocha of the creation —	765	1	3950
3	The ſame by the Greek emperors ——	787	1	3926
4	The ſame in Mr Bedford's ſcripture chronology	706	1	4007
5	The ſame by Archbiſhop Uſher — —	710	1	4004
6	The deluge, or Noah's flood — —	2362	1657	2351
7	The Aſſyrian monarchy by Nimrod —	2665	1960	2048
8	The birth of Abraham — — —	2714	2009	1999
9	The Iſraelites 400 years ſervitude in Egypt	2819	2174	1894
10	The kingdom of Argos, founded by Inachus	2857	2152	1856
11	The kingdom of Athens, founded by Cecrops	3157	2452	1556
12	The Iſraelites departure out of Egypt —	3219	2514	1494
13	Their entrance into Canaan, or the jubilee	3258	2553	1533
14	The deſtruction of Troy — — —	3530	2825	1183
15	The firſt ſabbatical year — — —	3260	2557	1451
16	The Jewiſh high prieſthood — —	3300	2603	1405

17 King

		Jul. P.	A. M.	A. C.
17	King David's reign	3646	2941	1067
18	The foundation of Solomon's temple	3698	2993	1015
19	The epohca of Nabonaſſar	3966	3261	747
20	The Olympiads	3938	3233	775
21	The building of Rome	3962	3257	751
22	The ſame, by Archbiſhop Uſher	3966	3261	748
23	The deſtruction of the kingdom of Iſrael	3992	4287	721
24	The Babyloniſh captivity	4108	3302	606
25	The deſtruction of Solomon's temple	4126	3421	587
26	Cyrus, the founder of the Perſian monarchy	4178	3472	536
27	The battle at Marathon	4223	3517	491
28	Xerxes's defeat at the battle of Salamis	4234	3528	480
29	Meto began his cycle	4282	3576	432
30	The begining of the Peloponneſian war	4283	3577	431
31	Daniel's ſeventy weeks of years began	4269	3564	444
32	The beginning of the Calippic period	4383	3677	331
33	The death of Alexander	4390	3684	324
34	The Grecian epocha of the Seleucidæ	4402	3695	312
35	The æra of the Aſmoneans or Maccabees	4548	3841	166
36	The Antiochean epocha	4665	3958	49
37	The correction of the calendar by Julius Cæſar	4669	3962	45
38	The beginning of the reign of Herod	4677	3970	37
39	The Spaniſh æra	4676	3969	38
40	The battle at Actium	4683	3976	31
41	The epocha of the title of Auguſtus	4687	3980	27
42	The true birth of Chriſt	4710	4005	4
43	The vulgar or Dionyſian year of Chriſt's birth	4714	4009	A.D.
44	The paſſion or death of Chriſt	4746	4041	33
45	The deſtruction of the city of Jeruſalem	4783	4078	70
46	The Diocleſian or æra of martyrs	4997	4292	284
47	The epocha of Conſtantine the Great	5019	4314	306
48	The council of Nice	5038	4333	325
49	The Encænia of Conſtantinople	5043	4338	330
50	The epocha of the Hegira	5335	4610	622
51	The epocha of Jeſdegird	5345	4620	632
52	The Jellalæan or Gellalæan epocha	5792	5067	1079
53	The Gregorian epocha	6295	5590	1582

N. B. I have inſerted two epochas in this table, which, at firſt ſight, may be ſuſpected, becauſe the years before Chriſt do not correſpond (like the reſt) to the years of the Julian period; they are thoſe which Archbiſhop Uſher advances, viz. of the creation, and of the building of Rome; but the reader ought to be appriſed, that if the year in which our Lord was born be included, with the years preceding that time; then, to find the correſponding year of the period, he muſt ſubſtract from 4714, and the remainder gives it. But if the year of his nativity be omitted, then ſubſtraction is to be made from 4713; hence, we may learn, that authors, which agree in the year of the Julian period, may differ a year in their computations to the birth of Chriſt, for the reaſon aforeſaid.

REMARKS on the chief EPOCHAS in this TABLE.

N. B. The commencement of the following æras are adapted to the days of the month of the Julian computation.

Th

The æra of the world's creation, which reckons 3949 years before the birth of Chriſt; and which, according to the Julian account, began the 24th day of October.

The æra of the deſtruction of Troy begins June the 16th, as Scaliger proves out of Ephorus; 'tis very common in profane authors.

The æra of Nabonaſſar began on the 26th of February, 747 years before Chriſt. The year of Nabonaſſar wanted 6 hours of the Julian year, and therefore, the firſt day of it went back or began ſooner one day in 4 years, and one whole year in 1460 years; for 1460 Julian years made 1461 of Nabonaſſar's: Hence it came to paſs, that the Thoth, or firſt day of the year of Nabonaſſar 227, begun with the Julian year on the firſt of January; and that Julian year being leap-year, and ſo conſiſting of 366 days, the Thoth of the next year, 228 of Nabonaſſar, begun on the laſt of December in the ſame year, ſo that two years of Nabonaſſar began in one and the ſame Julian year; and the ſame thing happened again after 1460 Julian years, or 1461 years of Nabonaſſar, viz. in 1688 of that æra; and again, in 3149 of the ſame æra.

The chriſtian æra, from the birth of Chriſt, begins December the 25th.

The Turkiſh æra, or the Hegira, began on the 16th day of July, A. D. 622: This was occaſioned by Mahomet's flight; for he having exaſperated the chiefs of Mecca in Arabia by his falſe doctrine, they were reſolved to kill him; but, he having timely notice thereof, fled ſecretly by night, with all that would follow him, to Medina, another city of Arabia, where he ſettled himſelf, and built a Moſque for the exerciſe of his new religion; and order'd all computations of time to be made henceforwards from his ſaid flight, beginning as (their years are lunar) from the new moon of that time, but which they account not as others from the conjunction itſelf, but from the horning, which is the cauſe why they ſet upon their ſteeples a creſcent, as we a croſs on ours; ſo Hegira, which (in Arabic) ſignifies the flight of the perſecuted prophet in imitation of the Diocleſian æra.

The æra of the death of Alexander the Great, is the 12th of November, 324 years before Chriſt.

The Ethiopic, Abyſſine, or as ſome call it, the Diocleſian æra, others the æra of Martyrs, becauſe it bore date with a very ſevere perſecution: This æra began Auguſt the 29th, A. D. 284, and in the firſt year of the emperor Diocleſian; 'tis uſed by the Egyptians and Abyſſines.

The Perſic, or Jeſdegirdic æra, takes its date either from the coronation of the laſt Perſian king Jeſdegeris, Jeſdageris as ſome ſay, or from his being conquered by Ottoman the Saracen, which was June 16, A. D. 632.

The Julian æra takes its name from Julius Cæſar's reformation of the calendar, which was done 45 years before Chriſt, in the 708th year of the building of Rome, and 731ſt Olympiad.

The æra of the Olympiads begins from the new moon in the Summer ſolſtice 775 (tho' ſome will have it to commence 777) years before Chriſt; and the æra of Iphitus is only a collection of the Olympic years: Theſe two are the æras chiefly uſed by the Greek hiſtorians.

The Roman æra, from the building of the city, begins April the 21ſt, and is 752 years before Chriſt.

The Gregorian æra takes its name from Pope Gregory XIII. and began in October the 5th, 1582, and from the reformation of the calendar.

Theſe are the chief epochas which the learned have moſtly agreed on, as to the time of their commencing; but it is very common to find ſome variation among different writers of chronology, eſpecially in the æras of the creation, the building of Rome, and the Olympiads; which were all three eſtimated from aſtronomical tables, and adjuſted to the aſpects of the celeſtial bodies, as eclipſes, &c. which they acquired partly from the traditions of theſe times, and partly from conjecture. But ſince ſuch tables were not equally correct, they muſt conſequently differ in their computations.

To reduce the years of one epocha to thoſe of another, add the given year of an epocha to the year of the Julian period correſponding with its riſe, and that will give the year of the period, as was ſhewn before.

CHAP. IV.

Of Golden Numbers and Epacts, ſhewing how to find them perpetually; with their Uſes in finding the moveable Feaſts, &c.

WHAT has been ſaid in the account of the Metonic period, may ſerve to define what the golden number is; and therefore I ſhall proceed to give you a rule to find it perpetually, viz. add unity, or 1, to the year of our Lord, (becauſe the firſt year of this cycle commenced the year before our Saviour was born) and divide the ſum by 19, the quotient ſhews how many revolutions were made ſince that time, and the remainder (if any) is the year of the cycle or golden number for that year; but if there be no remainder, then it is the laſt year of the cycle, and conſequently 19 is the golden number.

EXAMPLE: What is the golden number for 1758?

1758
1

19) 1759 (92
171

49
38

Remainder 11 is the golden number for this year; 12 for the next, &c. increaſing by 1 till 19.

The golden numbers were placed in a column to the left hand in every month, in the calendar of our Common-Prayer books, whoſe uſe, at firſt, was to find the new moons and Eaſter-day in the Julian account; but, though at the end of 19 years, the ſame lunations always return on the ſame day, yet they happen not on the ſame preciſe time of the day, for they recur 1 hour, 27 minutes, 23 ſeconds ſooner in every ſucceding period; which, in proceſs of time, will amount to a day, and if not rectified, the error will ſtill be greater. For it is eaſy to calculate from the aforeſaid data, that in about 312 years and ½, the lunations will gain a day on the beginning of the month; ſo that, when they came to reform the calendar, the lunations happened in the heavens 4 or 5 days ſooner than ſhewn by the golden number; for, in this particular, the ancients were miſtaken, taking the uſe of the golden number to be more ſure and infallible than it is: For it is plain, that the golden number will not ſhew the true change of the moon for more than 312 years without being varied. It is to be obſerved, that the golden number is not ſo well adapted to the Gregorian as to the Julian account, becauſe when a centeſimal common year falls within the cycle, it will move the new moons a day later in the calendar than otherwiſe they would have fallen, inſomuch that a new moon which fell before the centeſimal year, ſuppoſe on March 10, will fall 19 years afterwards on March 11. Its uſe, in finding the new moons being greatly neglected ſince the reformation of the calendar, the epact being more certain in the new ſtile, to find which the golden number is ſtill of uſe; yet the golden number retains a place in the new calendar of our common-prayer books, between the 21ſt of March and the 18th of April, to denote the days upon which the paſchal full moons do fall, and thereby to determine Eaſter-day in thoſe years, of which they are reſpectively the golden numbers; and here it may not be amiſs to ſhew how they may be found perpetually.

There are two tables at the latter end of the calendar, which I ſhall tranſcribe; a ſight them will inform the reader better than a multiplicity of words.

1	2	3	1	2	3	1	2	3	1	2	3
	Year of our Lord			Year of our Lord.			Year of our Lord.			Year of our Lord.	
B	1600	0		3400	8	B	5200	15		7000	24
	1700	1		3500	9		5300	16		7100	24
	1800	1	B	3600	8		5400	17	B	7200	24
	1900	2		3700	9		5500	17		7300	25
B	2000	2		3800	10	B	5600	17		7400	25
	2100	2		3900	10		5700	18		7500	26
	2200	3	B	4000	10		5800	18	B	7600	26
	2300	4		4100	11		5900	19		7700	26
B	2400	3		4200	12	B	6000	19		7800	27
	2500	4		4300	12		6100	19		7900	28
	2600	5	B	4400	12		6200	20	B	8000	27
	2700	5		4500	13		6300	21		8100	28
B	2800	5		4600	13	B	6400	20		8200	29
	2900	6		4700	14		6500	21		8300	29
	3000	6	B	4800	14		6600	22	B	8400	29
	3100	7		4900	14		6700	23		8500	0
B	3200	7		5000	15	B	6800	22			
	3300	7		5100	16		6900	23			

This table is computed to the period of 6900 years, viz. from 1600 to 8500. In the firſt column, the letter B is placed againſt every 400th year through the ſaid period, which denotes that the years againſt which it ſtands are to be accounted biſſextile or leap-years; the reſt being all common years according to the Gregorian form. In the ſecond, are the centeſimal years of the chriſtian æra: And in the third, are the ſeveral in-

indices of the epacts correſponding to theſe centuries. Now it is proper to obſerve, that the ſame index will ſometimes ſerve two centuries, and ſometimes three without being changed. For inſtance, the ſame index 1 ſerves for both 1700 and 1800, and the index 2 ſerves for three centuries, viz. for 1900, 2000 and 2100: This being premiſed, I ſhall proceed to ſhew their uſe.

With the index 1 I can find annually the day of the paſchal full moon, from 1700 to 1899; for beginning with the golden number 1, at the top of the next table, and looking down the column under it, I find the index 1 right againſt the 13th day of April, which denotes that the prime 1 muſt be placed againſt the 13th of April, which you will find inſerted in the calendar.

The GOLDEN NUMBERS.

Paſch. fullM.	Sund. Letter	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
M 21	C	8	19	0	11	22	3	14	25	6	17	28	9	20	1	12	23	4	15	26
M 22	D	9	20	1	12	23	4	15	26	7	18	29	10	21	2	13	24	5	16	27
M 23	E	10	21	2	13	24	5	16	27	8	19	0	11	22	3	14	25	6	17	28
M 24	F	11	22	3	14	25	6	17	28	9	20	1	12	23	4	15	26	7	18	29
M 25	G	12	23	4	15	26	7	18	29	10	21	2	13	24	5	16	27	8	19	0
M 26	A	13	24	5	16	27	8	19	0	11	22	3	14	25	6	17	28	9	20	1
M 27	B	14	25	6	17	28	9	20	1	12	23	4	15	26	7	18	29	10	21	2
M 28	C	15	26	7	18	29	10	21	2	13	24	5	16	27	8	19	0	11	22	3
M 29	D	16	27	8	19	0	11	22	3	14	25	6	17	28	9	20	1	12	23	4
M 30	E	17	28	9	20	1	12	23	4	15	26	7	18	29	10	21	2	13	24	5
M 31	F	18	29	10	21	2	13	24	5	16	27	8	19	0	11	22	3	14	25	6
Ap 1	G	19	0	11	22	3	14	25	6	17	28	9	20	1	12	23	4	15	26	7
A 2	A	20	1	12	23	4	15	26	7	18	29	10	21	2	13	24	5	16	27	8
A 3	B	21	2	13	24	5	16	27	8	19	0	11	22	3	14	25	6	17	28	9
A 4	C	22	3	14	25	6	17	28	9	20	1	12	23	4	15	26	7	18	29	10
A 5	D	23	4	15	26	7	18	29	10	21	2	13	24	5	16	27	8	19	0	11
A 6	E	24	5	16	27	8	19	0	11	22	3	14	25	6	17	28	9	20	1	12
A 7	F	25	6	17	28	9	20	1	12	23	4	15	26	7	18	29	10	21	2	13
A 8	G	26	7	18	29	10	21	2	13	24	5	16	27	8	19	0	11	22	3	14
A 9	A	27	8	19	0	11	22	3	14	25	6	17	28	9	20	1	12	23	4	15
A 10	B	28	9	20	1	12	23	4	15	26	7	18	29	10	21	2	13	24	5	16
A 11	C	29	10	21	2	13	24	5	16	27	8	19	0	11	22	3	14	25	6	17
A 12	D	0	11	22	3	14	25	6	17	28	9	20	1	12	23	4	15	26	7	18
A 13	E	1	12	23	4	15	26	7	18	29	10	21	2	13	24	5	16	27	8	19
A 14	F	2	13	24	5	16	27	8	19	0	11	22	3	14	25	6	17	28	9	20
A 15	G	3	14	25	6	17	28	9	20	1	12	23	4	15	26	7	18	29	10	21
A 16	A	4	15	26	7	18	29	10	21	2	13	24	5	16	27	8	19	0	11	22
A 17	B	5	16	27	8	19	0	11	22	3	14	25	6	17	28	9	20	1	12	23
A 18	B	6	17	28	9	20	1	12	23	4	15	26	7	18	29	10	21	2	13	24
A 18	C C	7	18	29	10	21	2	13	24	5	16	27	8	19	0	11	22	3	14	25

From each golden number, look down the column it ſtands in for the index of the given century; and, on the left hand, in the horizontal row, in the column under paſchal full moon ſtands the month and day, to which the golden number muſt be prefix'd during that century.

Thus, again, as the table intimates, looking down the column of the golden number 2 for the index 1, I find it ſtands againſt the 2d day of April; alſo looking the column under the golden number 3 for the index 1, I find it ſtands againſt the 22d day of March; therefore, it is obvious why the golden number 2 ſhould be placed againſt the 2d day of April, and the golden number 3 againſt the 22d day of March: In like manner, looking for the index 1, under the reſt of the golden numbers, and guiding your eye ſide-ways to the left hand, in the firſt column of the table always you will find the month and day to which the golden number (which ſtands above the ſaid index) ought to be prefixed in the calendar; having thus found how to place the golden numbers, you might make a ſmall table to find Eaſter-day for ſo many centuries as the index remains permanent or unchanged. Now you will find two ſuch tables already made in the new calendars of your common-prayer books, one from the year 1700 to 1899, becauſe the ſame index (viz. 1) ſerves both centuries; and another from 1900 to 2199, for the index (viz. 2) remains permanent, during 3 centuries. I have tranſcribed them both, as ſpecimens, to form others by when occaſion requires.

A Table to find Eaſter Day from the Year 1700 to the Year 1899.

Golden Number.	Day of the Month.	Sunday Letter.	Golden Number.	Day of the Month.	Sunday Letter.
14	March 21	C	15	April 9	A
3	—— 22	D	4	—— 10	B
	—— 23	E		—— 11	C
11	—— 24	F	12	—— 12	D
	—— 25	G	1	—— 13	E
19	—— 26	A		—— 14	F
8	—— 27	B	9	—— 15	G
	—— 28	C		—— 16	A
16	—— 29	D	17	—— 17	B
5	—— 30	E	6	—— 18	C
	—— 31	F		—— 19	D
13	April 1	G		—— 20	E
2	—— 2	A		—— 21	F
	—— 3	B		—— 22	G
10	—— 4	C		—— 23	A
	—— 5	D		—— 24	B
18	—— 6	E		—— 25	C
7	—— 7	F			
	—— 8	G			

Note, Theſe are the ſame with thoſe in the calendar, between March 21 and April 18.

To uſe theſe tables, or any other of the like kind, look for the golden number of the year in the firſt column of the table, againſt which ſtands the day of the paſchal full moon; then look in the third column for the Sunday letter, next after the day of the full moon, and the day of the month ſtanding againſt that, Sunday letter is Eaſter-day. If the full moon happens upon a Sunday, then (according to the firſt rule) the next Sunday after is Eaſter-day.

A Table to find Eaſter Day from the Year 1900 *to the Year* 2199 *incluſive.*

Golden Number.	Day of the Month.	Domin. Letter.	Golden Number.	Day of the Month.	Domin. Letter.
14	March 22	D	15	April 10	B
3	——— 23	E	4	——— 11	C
	——— 24	F		——— 12	D
11	——— 25	G	12	——— 13	E
	——— 26	A	1	——— 14	F
19	——— 27	B		——— 15	G
8	——— 28	C	9	——— 16	A
	——— 29	D	17	——— 17	B
16	——— 30	E	6	——— 18	C
5	——— 31	F		——— 19	D
	April 1	G		——— 20	E
13	——— 2	A		——— 21	F
2	——— 3	B		——— 22	G
	——— 4	C		——— 23	A
10	——— 5	D		——— 24	B
	——— 6	E		——— 25	C
18	——— 7	F			
7	——— 8	G			
	——— 9	A			

Before I conclude this ſubject, it remains that I ſhould give ſome account how theſe numbers, viz. the indices, came to be placed in the columns under the golden numbers, in the manner we ſee them; and alſo of the conſtruction of the reſt of the table, for though I have ſhewn its uſe, in framing theſe little tables from it, I have taken no notice as yet how it came to be ſo formed. Now, it muſt be obſerved, that the Nicene council fixed the vernal equinox to the 21ſt of March, and appointed the firſt full moon, which happens after it, to be the boundary of Eaſter, which is therefore called the paſchal term; and the earlieſt paſchal term, being the 21ſt of March, and the next Sunday after, being Eaſter-day, 'tis plain the earlieſt Eaſter poſſible is the 22d of March, and the 18th of April being the lateſt paſchal term that can happen; the 7th day after, viz. the 25th of April, is the lateſt Eaſter poſſible: Hence, we ſee the reaſon why, in the firſt column of the table, are placed the days of the paſchal full moon, from March 21 to April 18; and alſo the reaſon why, in framing the little tables from the table, I am deſcribing, that the days of the month and dominical letters are continued to the 25th of April, when the golden numbers never exceed the 18th; but, to return, the column of Sunday letters are the ſame, and come in due courſe among thoſe in the calendar. The golden numbers which are placed on the top of the columns and begin with unity or 1, and increaſe by one every year, viz. the 2d year 2, the 3d year 3, &c. to 19, which is the end of the cycle; and, the next year, it begins with 1 again, and ſo on perpetually, will ſerve for any future century. Laſtly, the indices are ſo ranged in each column, that thoſe of the ſucceeding column exceed thoſe of the preceding one by 11, always ſubducting 30 from the ſum, when it amounts to 30 or more.

For inſtance 8, the firſt or higheſt index, is placed under the golden number 1; then 19, the firſt index of the third column, is placed under the golden number 2: Now 19 is 11 more than 8, but the firſt index in the fourth column, under the golden number 3, is 0, becauſe 19 and 11 make 30; from which abate 30, and the remainder is 0; then 11, the firſt index of the 5th, is placed under the golden number 4, &c. for the reſt; from hence it follows, that the day of the paſchal full moon falls 11 days ſooner in the following year, than in the preceding one. This will be better underſtood when I treat of the epact.

It muſt be obſerved, that the lunar cycle was invented to ſhew the changes of the moon and the time of Eaſter, and other moveable feaſts; and that, by means of thoſe numbers, called epacts. Theſe epacts are (as their name implies) added numbers, that is, a number of days added to the lunar year to make it even or equal to the ſolar year; it comes from Epiago, which imports a going round, becauſe it goes round with the lunar cycle. Epacts are of two kinds, viz. are menſtrual and annual; menſtrual epacts are the exceſſes of the civil or calendar, above the lunar month. Suppoſe, for example, it were new moon the 1ſt day of January; ſince the lunar months is 29 days, 12 hours, 44 minutes, 3 ſeconds, and the month of January contains 31 days, the menſtrual epact is 1 day, 11 hours, 15 minutes, 57 ſeconds. The ancient annual epact, was the exceſs of the Julian ſolar year of 365 days, 6 hours, above the Julian lunar year, which is 354 days, 8 hours, 48 minutes, and 38 ſeconds: Therefore the annual epact will be 10 days, 21 hours, 11 minutes, 22 ſeconds. Now, as this difference does not want 3 hours of 11 days, the ancients took no notice thereof, but made the epact of the firſt year of the cycle 11 days, whence the epact of the ſecond year would be 22 days, and the epact of the third 33; but, for each 30 days, they intercalated a month, and reckon'd the odd 3 days the epact for that year; and thus they proceeded, by adding 11 days, and intercalating a month for every 30, till, at the end of 19 years, nothing remaining of the former epact (which, for the laſt or 19th year, was always 12) there began a new or ſecond revolution of the epacts and golden numbers. From what has been ſaid, it is evident, that, in the courſe of a cycle, there are ſeven intercalary months, viz. one in the 3d, 6th, 9th, 11th, 14th, 17th, and 19th year of the cycle. But, notwithſtanding all their care of epacts and embolimic months, this cycle was ſtill defective; for the epact of 11 days exceeds the true epact of 10 days, 21 hours, 11 minutes, and 22 ſeconds, by 2 hours, 48 minutes, and 38 ſeconds, which, in 19 years, make 2 days, 5 hours, 24 minutes, and 2 ſeconds. To equibalance this exceſs, the 7 embolimic months were made to conſiſt of 30 days each, which is more than the ſynodical month by 11 hours, 15 minutes, and 57 ſeconds: This exceſs, multiplied by 7, makes 3 days, 6 hours, 51 minutes, 39 ſeconds; but this again over-balances the former exceſs by 25 hours, 27 minutes, and 37 ſeconds; therefore, allowing 12 days inſtead of 11, for the epact of the laſt year of the cycle, to anſwer theſe odds, 'tis plain the ſolar year will, at the end of the cycle, be greater than the lunar year by about 1 hour, 27 minutes, and 37 ſeconds; tho' I believe, in ſtrictneſs, it will be but 1 hour, 27 minutes, and 33 ſeconds, this difference of 4 ſeconds, being occaſioned by neglecting the thirds in the operation: But though this deficiency of the cycle be ſmall, yet, in time, it becomes very ſenſible; for, by this analogy,

h. min. ſec. years. h. years.
1 27 33 : 19 : : 24 : 312½

'Tis plain, in the ſpace of 312½ years, it amounts to one day. Now, the council of Nice, A. D. 325, fitting this cycle of the moon to the calendar, it did nearly enough, for ſome time, give the new moons.

But the lunations in every 312½ years, anticipating a whole day; and ſince, the ſaid council have paſſed 4½ times 312½ years, the new moons happen ſooner by above 4½ days, at this time, by the golden number, according to the Julian method, than they really do in the heavens; yet, notwithſtanding this, the church of England retain'd this old erroneous way of computing the lunations till A. D. 1752; and her doctors, when they ſpoke of thoſe falſe and erroneous new and full moons, to take off the odium, refin'd the expreſſion into an eccleſiaſtical one. Since the new moons have thus anticipated, the epacts muſt have decreaſed in the ſame proportion, as the new moons anticipated, in order to find the time of the new and full moons by the epacts; whence it follows, that, before we can find the epacts, according to the Gregorian calendar, we muſt find how many days the Gregorian ſtyle has gained of the Julian, which may be performed by the following rule: Reject two figures or cyphers to the right hand, and divide the remaining numbers or cyphers by 4; reject the remainder, and add 2 to the quotient, this ſum ſubſtracted from the figures, cut off to the left hand, gives the number of days anticipated. Thus, in the year 1700, I would know how many days the Gregorian ſtile has gained of the Julian.—Operation,

4) 17|00 (4 quotient.

Then to the quotient 4 add 2, and the ſum will be 6, which ſubtracted from 17, the remainder 11 will be the number of days the Gregorian ſtile has gained of the Julian. Then, to find the Gregorian epact, firſt find the Julian epact by the following rule: Multiply the golden number, for the current year of Chriſt by 11, and divide the product by 30, the quotient, if there be any, will ſhew how many embolimæan or interlary months have happened ſince the firſt year of the cycle, and the remainder is the epact for that year; then ſubſtract the number of days that the Gregorian ſtile has gained of the Julian, from the Julian epact, and the remainder will be the Gregorian epact; but if ſubſtraction cannot be made, you muſt add 30 as often as needful. Thus, if it were required to find the Gregorian epact for the year 1700, firſt 10 being the golden number for that year, which multiplied by 11, produces 110, which divided by 30, the quotient is 3, the number of embolimic months, and the remainder 20 is the Julian epact for that year; and the number of days anticipated is 11, which being taken from 20, gives 9 for the Gregorian epact required; but becauſe the epacts ſhould be decreaſed in proportion to the anticipation of the moon, therefore the above rule for finding the number of days anticipated will not ſerve any longer than the the year 1899, but by the help of the following table the epacts may be calculated for ever.

A

A TABLE *for calculating the* EPACTS *for ever.*

Nº	Years of our Lord.	Nº to be ſubtracted.	Nº	Years of our Lord.	Nº to be ſubtracted.	Nº	Years of our Lord.	Nº to be ſubtracted.
1	1600	10	25	4000	20	49	6400	0
2	1700	11	26	4100	21	50	6500	1
3	1800	11	27	4200	22	51	6600	2
4	1900	12	28	4300	22	52	6700	3
5	2000	12	29	4400	22	53	6800	2
6	2100	12	30	4500	23	54	6900	3
7	2200	13	31	4600	23	55	7000	4
8	2300	14	32	4700	24	56	7100	4
9	2400	3	33	4800	24	57	7200	4
10	2500	14	34	4900	24	58	7300	5
11	2600	15	35	5000	25	59	7400	5
12	2700	15	36	5100	26	60	7500	6
13	2800	15	37	5200	25	61	7600	6
14	2900	16	38	5300	26	62	7700	6
15	3000	16	39	5400	27	63	7800	7
16	3100	17	40	5500	27	64	7900	8
17	3200	17	41	5600	27	65	8000	7
18	3300	17	42	5700	28	66	8100	8
19	3400	18	43	5800	28	67	8200	9
20	3500	19	44	5900	29	68	8300	9
21	3600	18	45	6000	29	69	8400	9
22	3700	19	46	6100	29	1	8500	10
23	3800	20	47	6200	0	2	8600	11
24	3900	20	48	6300	1	3	8700	11

This table is computed to the period of 6900 years, which is numbered in the firſt columns, or thoſe marked Nº, from 1 to 69. The ſecond columns contain the entire hundred years from 1600 to 8700. And the third columns, the number which muſt be ſubtracted from the Julian epact, in order to find that of the Gregorian. Whence the number to be ſubtracted from the Julian epact for any year between 1600 and 8700 may be found by inſpection only: But if the given year ſhould exceed the limits of the table, we muſt find the number of the period applicable to it by the following rule.

Add to the entire hundred years the number 54, and if the ſum does not exceed 69, it is the number of the period; but if it exceeds 69, divide it by 69, and it will be the number of the period required.

Thus, if it were required to find the Gregorian epact for the year 325, being the year in which the council of Nice was holden, it will be 29.

For the entire hundred years are 3
To which add 54
The ſum 57 is the number of the period required.

Find this number in the firſt column marked N°, and right againſt it in the third column ſtands 4, the number to be taken from the Julian epact. Now the Julian epact for the year 325 is 3, to which add 30, (becauſe 4 cannot be ſubtracted from 3) take 4 from the ſum, and the remainder 29 will be the Gregorian epact required.

It remains that I ſhould ſhew how this Table was conſtructed: And firſt, it is proper to obſerve, if the new moons returned exactly at the ſame time after the expiration of 19 years, as the council of Nice ſuppoſed they would do, (when they fixed the rule for the obſervation of Eaſter, and marked the new moons in the calendar for each year of the lunar cycle) then the golden number multiplied by 11, would always give the epact: But in the Julian century, the new moons anticipate or happen earlier than the council imagined they would, by $\frac{8}{25}$ of a day. In the Gregorian common century, which is one day ſhorter than a Julian century, they happen $\frac{17}{25}$ of a day later (viz. from 1 day take $\frac{8}{25}$, and there remains $\frac{17}{25}$): Now $\frac{17}{25}$ multiplied by 3, gives $\frac{51}{25}$ for three common centuries; but $\frac{8}{25}$ being ſubtracted, on account of the Gregorian biſſextile century, there will remain $\frac{43}{5}$. Therefore in 4 Gregorian centuries the new moons will happen later by $\frac{43}{25}$ of a day, and the epacts muſt be decreaſed accordingly. At preſent the Gregorian epact is 11 days ſhort of the Julian epact; but the quotient of the number of centuries divided by 4, which at this time is 4, multiplied by $\frac{43}{25}$, with the addition of the remainder 1 multiplied by $\frac{17}{25}$, makes in all but $\frac{189}{25}$, or $7\frac{14}{25}$ days, therefore $\frac{86}{25}$, that is $3\frac{11}{25}$ days, muſt be added to compleat the 11 days. Whence we have the following general rule for finding the Gregorian epact for ever: Divide the centuries of any year of the Chriſtian æra by 4, (rejecting the ſubſequent numbers) multiply the remainder, if any, by 17, and to this product add the quotient multiplied by 43; add alſo 86, and divide the aggregate by 25; multiply the golden number by 11, from which ſubtract the laſt quotient, and, rejecting the thirties, the remainder will be the epact.

EXAMPLE for the Year 1758.

4) 17 (4
16

Remaind. 1
And 1 multiplied by 17 is 17.
The quotient 4 multiplied by 43 gives 172.

$$\text{Now the ſum of} \left\{ \begin{array}{r} 172 \\ 86 \\ 17 \end{array} \right.$$

Is 275 which divided by 25, quotes 11.
(the golden number) multiplied by 11, produces 121
From which take 11

Remaind. 110 which divided by 30, there will remain 20 for the epact.

By obſerving this rule ſtrictly, we may find the epact without the foregoing table; and by it the table was conſtructed; for the numbers which are to be ſubtracted from the Julian epact in each century, are only the reſpective quotients of the aggregate or ſum divided by 25: Thus, for 1600, the quotient will be 10, becauſe 4 divides 16 without a remainder,

der, you cannot multiply by 17; ſo you can only multiply 43 by 4, whoſe product is 172, to which add 86, and the ſum is 258; which divided by 25, the quotient is 10, as above. In 1700 the quotient is 11, becauſe the remainder 1 is multiplied by 17; which being added to 258, makes 275; and this divided by 25 will quote 11. And in 1800, the quotient can only be 11, becauſe the number 292, to be divided by 25, only exceeds 11 times 25 by 17, ſo 25 cannot be contained 12 times therein. But in the next century, viz. 1900, the quotient will be 12, becauſe 3 multiplied by 17, produces 51; which added to 258, makes 309; ſo that 25 is 12 times found in it. In like manner are the reſt of the numbers in the table found.

But when the quotient amounts to 30, as in 6200, and as 30 is to be rejected, nothing muſt be taken from the Julian epact during that century which is the radix of the table. From what has been ſaid, we may infer that all the mutations that can poſſibly happen the numbers in the table, are included in 69 centuries, viz. from 0 to 29, in the numbers to be ſubtracted. The firſt year of Chriſt is reckoned the 54th year of this cycle. Hence we know the reaſon why we muſt add the number of centuries elapſed ſince that time to 54: After the expiration of this period if the ſum divided by 69 leave a remainder, it muſt be the number applicable to the next period; but if it leaves none, then it is the laſt year of another period.

It is alſo obſervable, that theſe numbers which are to be ſubtracted from the Julian epact, are regulated according to the Metemptoſis and Proemptoſis.

At preſent the firſt year of the cycle of the moon, the epact is 0, becauſe the lunar year begins with the ſolar. On the ſecond, the lunar year has begun 11 days before the ſolar year, therefore the epact is 11. On the third, it has begun twice 11 before the ſolar year, therefore the epact is 22. On the fourth, it begins 3 times 11 days ſooner than the ſolar year, the epact would therefore be 33; but 30 days being a ſynodical month, muſt that year be intercalated, or that year muſt be reckoned to conſiſt of 13 ſynodical months, and there remains 3, which is the true epact of the year; and ſo on to the end of the cycle, adding 11 to the epact of the laſt year, always rejecting 30, gives the epact of the preſent year.

Thus to adjuſt the lunar year to the ſolar through the whole of 19 years, 12 of them muſt conſiſt of 12 ſynodical months each, and 7 of 13, by adding a month of 30 days to every year when the epact would exceed 30, and a month of 29 to the laſt year of the cycle, which makes in all 209 days, i. e. 19 multiplied by 11: ſo that the intercalary, or embolimean years, in this cycle, are 4, 7, 10, 12, 15, 18, 19.

Note, The epact of any year expreſſes the number of days from the laſt new moon of the old year (which was the beginning of the preſent lunar year) to the 1ſt of January.

As the above rules for finding the epact may ſeem tedious, eſpecially to ſuch as are not well verſed in numbers, I ſhall add a ſhort rule, which will ſerve till the year 1900.

Subtract 1 from the golden number, multiply the remainder by 11, reject the thirties, and you will have the epact.

EXAMPLE for the year 1758.

Golden number	11
From which take	1
Remaind.	10
Which mult. by	11
Product	110
From which take thrice 30, or	90
Remaind.	20 is the epact.

A TABLE *of the* GOLDEN NUMBERS *and the correſponding* EPACTS, *till the Year* 1900.

G. N.	Epact.	G. N.	Epact.	G. N.	Epact.	G. N.	Epact.
1	0	6	25	11	20	16	15
2	11	7	6	12	1	17	26
3	22	8	17	13	12	18	7
4	3	9	28	14	23	19	18
5	14	10	9	15	4		

CHAP. V.

Of the Dominical Letters. Shewing how to find them perpetually: With Tables of the ſame.

DOminical Letter, is that letter of the alphabet which points out in the calendar the Sundays throughout the year, thence called the Sunday letter. The diſtribution of days into weeks is made by the ſeven firſt letters of the alphabet, A, B, C, D, E, F, G, beginning at the 1ſt of January to place the letter A; to the 2d B is joined; to the 3d C, and ſo on to the 7th, where G is figured: And then again beginning with A, which is placed at the 8th day, B will be at the 9th, C at the 10th; and ſo continually repeating the ſeries of theſe ſeven letters, each day of the year has one of them in the calendar. By this means the laſt of December has the letter A joined to it; for if the 365 days, which are in a year, be divided by 7, we ſhall have 52 weeks, and 1 day over. If there had been no day over, all the years would conſtantly begin on the ſame day of the week, and each day of the month would conſtantly have fallen on the ſame day of the week; but now on account, that beſides the 52 weeks in the year, there is one day more, it happens that on whatever day of the week the year begins, it ends upon the ſame day, and the next year begins with the following day.

The letters ranked in this order, that letter which anſwers to the firſt Sunday of January in a common year, will ſhew all the Sundays throughout the year: And to whatever days in the reſt of the months that letter is put, theſe days are all Sundays. If the 1ſt day of January be on a Sunday, the next year will begin on a Monday, and the Sunday will fall on the 7th day, to which is annexed the letter G, which will therefore be the

Sunday letter for that year. The next year beginning on Tueſday, the firſt Sunday letter will fall on the 6th of January, to which is adjoined the letter F, which is the Sunday letter for that year: And ſo in the ſame manner for the next following, the dominical letter will be E, and ſo on: By this means the Sunday letters will go on in a retrograde order, viz. G, F, E, D, C, B, A. But becauſe every 4th year conſiſts of 366 days, the ſeries of letters will be interrupted, and the order will not return till 28 years, or 4 times 7; And hence ariſes the cycle of 28 years, (of which I diſcourſed before under the title of cycle of the ſun or ſolar cycle): Thus, if in a leap year the 1ſt of January be Sunday, and conſequently the dominical letter A, the 24th day of February will fall on a Friday, and the 25th on a Saturday, and ſince both theſe days are marked in the calendar with the letter F, the following day, which is Sunday, will be marked with G, which letter will mark out all the Sundays, and conſequently be the dominical letter the remaining part of the year. And hence it is, that every leap year has two dominical letters, the firſt of which ſerves from the beginning of the year to the 24th or 25th day of February, and then the other takes place and ſerves for the reſt of the year. The intercalary day is placed between the 23d and 24th day of February, and ſo makes two 24ths of February, which in the calendar is eſteemed as one and the ſame day, and have the ſame letter affixed to them; but by our way of reckoning, they are called the 24th and 25th days of February.

For finding the dominical letter.—Divide the year and its 4th part (omitting fractions) by 7, and the remainder being taken from 7, the laſt remainder will be the index of the dominical letter, reckoning A 1, B 2, C 3, &c. Thus if it were required to find the dominical letter for the year 1758.——Operation:

4) 1758
439

7) 2197 (313

Remaind. 6 which ſubtracted from 7, the Index will be 1, which correſponds to the letter A. But as the years 1800, 1900, 2100, 2200, 2300, &c. according to the new ſtile, conſiſt of 365 days only, they therefore have but one dominical letter, whereas according to the Julian calendar they would have two: For this reaſon the dominical letters will be changed, and conſequently this of finding the dominical letter will only hold good for this century; after which a number muſt be added to the year and its 4th, in order to find the dominical letter for ever. For this purpoſe obſerve the following rule: Reject the figures or cyphers to the place of hundreds; divide the remaining figures or cyphers by 4; from this quotient ſubtract 1; this number ſubtracted from the hundred years, and then this laſt remainder taken from the leaſt number of ſevens poſſible, leaves a number which muſt be added to the year and its fourth in order to find the dominical letter.

Example: What will be the dominical letter for the year 1842?

This queſtion by the above rule will be ſolved in the following manner,

4) 18 (4 quotient,
16

Remaind. 2

From the quotient 4 take 1, and the remainder 3 taken from 18 gives 15, which being ſubtracted from 21, the neareſt ſevens, gives 6, the number to be added.

Then to the given year 1842
Add its 4th part 460
And the number ſound 6

7) 2308 (329

Remaind. 5 which taken from 7, leaves the Index of the letter B, the dominical letter required.

But in the new calendar of our common prayer books, there is a perpetual table, whereby the dominical letters may be found in any century: A Tranſcript of which you have as follows :

The TABLE.

6	5	4	3	2	1	0
B	C	D	E	F	G	A
				1600	1700	1800
1900 2000	2100	2200	2300 2400	2500	2600	2700 2800
2900	3000	3100 3200	3300	3400	3500 3600	3700
3800	3900 4000	4100	4200	4300 4400	4500	4600
4700 4800	4900	5000	5100 5200	5300	5400	5500 5600
5700	5800	5900 6000	6100	6200	6300 6400	6500
6600	6700 6800	6900	7000	7100 7200	7300	7400
7500 7600	7700	7800	7900 8000	8100	8200	8300 8400
8500	&c.					

It is evident by mere inſpection that this table may be continued at pleaſure, by keeping to the form and enlarging the ſeries.

Now to find the dominical letter for any given year of our lord ; add to the year its 4th part, omitting fractions, and alſo the number which ſtandeth at the top of the column, wherein the number of hundreds contained in that given year is ſound ; divide the ſum by 7, and if there is no remainder,

mainder, then A is the Sunday letter; but if any number remaineth, then the letter which ſtandeth under that number at the top of the table is the Sunday letter.

Example: To find the dominical letter for the year 1842.

Now a cypher being placed above 1800, therefore you can add nothing to the year and its fourth; but their ſum 2302, being divided by 7, the remainder will be 6, (for you have nothing to do with the quotient here) then looking for 6 at the top of the table, under it you have the letter B, which is the dominical letter for that year.

Note, That in all biſſextile or leap years, the letter found as above will be the Sunday letter from the intercalated day excluſive, to the year's end.

There is alſo another method of finding the dominical letter by the cycle of the ſun (page 11); and becauſe I have been too prolix in giving examples to the rules for finding the three famous cycles, viz. of the ſun, moon, and indiction, I ſhall here repeat an abridgement of all the three comprized in the following verſe, which will alſo be immediately exemplified.

When 1, 9, 3, to th' year hath added been,
Divide by 19, 28, and 15,

Examples for the year 1758.

If 1 be added to the year, and the ſum 1759 be divided by 19, the remainder 11 is the golden number. Again, if 9 be added to the year 1758, and the ſum 1767 divided by 28, the remainder 3 is the cycle of the ſun, and A the correſpondent dominical letter. Laſtly, 3 added to 1758, and the ſum 1761 divided by 15, the remainder 6 is the indiction.

A TABLE, *ſhewing the* DOMINICAL LETTER *at Sight, according to the Gregorian or New Stile.*

Years above Hundreds.				Hundreds of years.			
				100	200	300	400
				500	600	700	800
				900	1000	1100	1200
				1300	1400	1500	1600
				1700	1800	1900	2000
				2100	2200	2300	2400
				2500	2600	2700	2800
				2900	3000	3100	3200
				3300	3400	3500	3600
				3700	3800	3900	4000
				4100	4200	4300	4400
				C	E	G	B A
1	29	57	85	B	D	F	G
2	30	58	86	A	C	E	F
3	31	59	87	G	B	D	E
4	32	60	88	F E	A G	C B	D C
5	33	61	89	D	F	A	B
6	34	62	90	C	E	G	A
7	35	63	91	B	D	F	G
8	36	64	92	A G	C B	E D	F E
9	37	65	93	F	A	C	D
10	38	66	94	E	G	B	C
11	39	67	95	D	F	A	B
12	40	68	96	C B	E D	G F	A G
13	41	69	97	A	C	E	F
14	42	70	98	G	B	D	E
15	43	71	99	F	A	C	D
16	44	72		E D	G F	B A	C B
17	45	73		C	E	G	A
18	46	74		B	D	F	G
19	47	75		A	C	E	F
20	48	76		G F	B A	D C	E D
21	49	77		E	G	B	C
22	50	78		D	F	A	B
23	51	79		C	E	G	A
24	52	80		B A	D C	F E	G F
25	53	81		G	B	D	E
26	54	82		F	A	C	D
27	55	83		E	G	B	C
28	56	84		D C	F E	A G	B A

USE of this TABLE.

Under the hundreds, and againſt the odd years, ſtands the dominical letter or letters for the year required, N. S.

EXAMPLE. Under 1700, and againſt 58, ſtands the dominical letter A for 1758.

N. B. The dominical letter for even huudreds ſtands under thoſe hundreds.

It is very eaſy to conceive how this table has been conſtructed, ſince we can enlarge it at pleaſure, by only ranging the hundreds of Chriſt in the ſame manner as thoſe in the table. The four columns of dominical letters are only four ſolar cycles adapted to four different centuries.

CHAP

CHAP. VI.

A Synodical Month what. Rules for the Moon's Age: To find what Sign ſhe is in, &c. A Theory of the Moon; and an Account of the Harveſt Moon.

IT was obſerved, that a ſynodical month, which is the ſpace of time contained between the moon's parting from the ſun at conjunction, and returning to him again, during which time ſhe puts on all her phaſes, was 29 days, 12 hours, 44 minutes, 3 ſeconds, and 11 thirds; this is to be underſtood of a mean ſynodical month, but a ſynodical month is unequal in every month in the year. For in December, about the winter ſolſtice, when the earth is in perihelion or neareſt the ſun, the time between one conjunction of the ſun and moon and the next, is more by about 12 hours than it is in June, about the ſummer ſolſtice, when the earth is in aphelion, or at the greateſt diſtance from the ſun; which in the firſt caſe, is about 29 days, 19 hours, and in the latter, 29 days, 7 hours: The reaſon of which is very plain; for the earth (or ſun apparently) moving faſter in December than it does in June, of neceſſity there muſt be more time ſpent for the moon to come up to conjunction with the ſun in the former than in the latter. And for this reaſon the moſt exact method of finding the changes of the moon is by aſtronomical tables, whereby they may be calculated to the moſt ultimate degree of exactneſs. But ſince ſuch tables, and the precepts for uſing them, would ſwell the book beyond the prefixed limits, and to little purpoſe for any, (except ſuch as are acquainted with aſtronomical calculations) they being ſo difficult to be underſtood, that I preſume they would be rendered impracticable. Therefore I intend to ſubſtitute in their room a ſhort rule for finding both age and change, according to the mean motion of the moon.

Janus 0, 2, 1, 2, 3, 4, 5, 6,
8, 8, 10, 10, theſe to the epact fix;
The ſum, 'bate 30 to the month's day add,
Or take from 30, age, or change is had.

This rule, when once underſtood, is both eaſy to get by heart, and retain in mind.

By Janus is underſtood January, which was thus called becauſe the antient Romans dedicated the firſt month of their year to Janus, a pretended deity, who was ſuppoſed to preſide over the beginning of all buſineſs. So that for January you muſt add 0 to the epact, Feb. 2, March 1, April 2, May 3, June 4, July 5, Auguſt 6, Sept. 8, Oct. 8, Nov. 10, Dec. 10; if the ſum be under 30, ſubtract it from 30, and it will give the day of the change in that month; but if the ſum exceed 30, ſubtract it from 59, and the remainder is the day of the new moon according to the middle motion.

The day of the full moon is gained by ſubtracting the abovementioned ſum from 15; but when ſubtraction cannot be made, borrow 30 days, and the remainder will give you the day of the full moon according to her mean motion.

The moſt uſual method of finding her age is to add the day of the month and the number of the month to the epact, the ſum (if it exceeds not 30) is her age; but if it doth, ſubtract 30 as oft as you can, and the remainder is her age.

EXAMPLES in each Caſe.

Let it be required to find when the moon will change in April 1758?

The Epact for the year is 20
Nº of the month 2
—
Sum 22
Taken from 30
—
Remaind. 8 the day of the change in April 1758.

Now to find when ſhe will be at full, I find I cannot take 22 (the aforeſaid ſum) out of 15, but by adding 30 to it the ſum is 45, from which I take 22, and there remains 23, for the day of that month ſhe will be at full.

And to find her age at any time, ſuppoſe on the 15th of the ſaid month?

The Epact is 20
Nº of the month 2
Day of the month 15
—
Sum 37
From which take 30
—
Remainder 7 is the day of the moon's age on the 15th of April, 1758.

A

A TABLE, *ſhewing the New, Full, and Quarter Moons till the Year* 1900, *according to the Gregorian Stile.*

Gold. Num.	January.				Gold. Num.	February.				Gold. Num.	March.				Gold. Num.	April.				Gold. Num.	May.				Gold. Num.	June.			
	N. M.	F. Q.	F. M.	L. Q.		N. M.	F. Q.	F. M	L. Q.		N. M.	F. Q.	F. M.	L. Q.		N. M	F. Q.	F. M.	L. Q.		N. M.	F. Q.	F. M.	L. Q.		N. M.	F. Q.	F. M.	L. Q.
	●	☽	○	☾		●	☽	○	☾		●	☽	○	☾		●	☽	○	☾		●	☽	○	☾		●	☽	○	☾
1	30	7	15	23	1	28	6	13	21	1	30	8	15	23	1	28	6	13	21	1	28	6	13	21	1	26	4	11	19
2	19	26	4	12	2	17	25	3	10	2	19	27	5	12	2	18	25	3	11	2	17	25	3	10	2	14	23	1.30	9
3	8	16	23	1.31	3	7	14	22	29	3	7	15	22	30	3	6	14	21	28	3	6	13	20	28	3	4	12	19	26
4	26	4	11	19	4	25	3	10	17	4	26	4	11	19	4	25	3	10	18	4	24	2	10	17	4	23	1.30	8	16
5	16	23	1.31	8	5	14	22	29	7	5	16	23	1.31	8	5	14	22	29	7	5	14	21	28	6	5	12	20	27	5
6	5	12	20	27	6	3	11	18	26	6	5	13	20	28	6	4	11	18	26	6	3	11	18	26	6	1.30	9	17	24
7	24	1,31	9	17	7	22	—	8	15	7	23	1.30	8	16	7	22	29	7	14	7	21	29	6	14	7	20	27	5	12
8	12	20	27	5	8	11	18	25	3	8	12	20	27	5	8	11	19	26	3	8	10	18	25	3	8	9	17	24	2
9	1.31	9	16	24	9	—	8	15	23	9	1.31	9	16	24	9	30	8	15	23	9	29	17	15	22	9	28	6	13	21
10	20	28	6	13	10	19	27	4	12	10	21	28	6	14	10	19	27	4	12	10	19	27	4	12	10	27	25	3	10
11	10	17	25	3	11	8	16	23	1	11	9	17	24	1.31	11	7	15	22	30	11	7	15	22	29	11	6	13	20	28
12	28	6	13	20	12	26	4	11	19	12	28	6	13	21	12	27	4	12	19	12	26	4	11	19	12	24	2	10	17
13	17	25	3	10	13	16	23	1	9	13	17	25	3	10	13	16	23	1.30	8	13	15	23	1.30	8	13	14	21	28	6
14	6	14	24	29	14	5	13	20	27	14	7	13	22	29	14	5	13	20	28	14	5	12	19	27	14	3	11	18	26
15	25	3	11	18	15	24	2	9	17	15	24	2	10	17	15	23	1.30	8	16	15	23	30	8	15	15	21	29	6	14
16	14	21	29	6	16	12	20	27	5	16	14	21	29	6	16	13	20	27	5	16	12	19	26	4	16	11	18	25	3
17	3	11	18	25	17	2	9	16	24	17	3	11	18	26	17	2	9	17	24	17	1.31	9	16	24	17	29	7	14	22
18	22	29	7	15	18	20	8	6	13	18	22	30	7	15	18	21	28	6	14	18	20	18	6	13	18	19	26	4	12
19	11	19	26	4	19	10	18	25	3	19	10	17	25	3	19	9	17	24	2	19	9	16	23	1.31	19	7	15	22	29

The TABLE *continued.*

Gold. Num.	July.				Gold. Num.	August.				Gold. Num.	September.			
	N. M.	F. Q.	F. M	L. Q.		N. M.	F. Q.	F. M.	L. Q		N. M.	F Q.	F. M.	L. Q.
	●	☽	○	☾		●	☽	○	☾		●	☽	○	☾
1	26	4	11	19	1	24	2	9	17	1	23	1.31	8	16
2	15	23	30	8	2	14	21	28	6	2	12	20	27	5
3	3	11	18	26	3	2	10	17	25	3	1.30	8	15	23
4	22	30	8	15	4	21	28	6	14	4	20	27	5	12
5	12	19	26	4	5	10	18	25	3	5	9	17	24	2
6	1.31	9	15	24	6	29	7	14	22	6	28	5	13	21
7	19	27	4	12	7	18	25	3	11	7	16	24	1	9
8	8	16	23	1.31	8	7	15	22	29	8	5	14	20	28
9	27	5	12	30	9	26	4	11	19	9	24	2	10	17
10	17	24	2	10	10	15	23	1.30	9	10	14	21	28	6
11	5	13	20	27	11	4	11	19	26	11	2	10	17	25
12	24	1.31	9	17	12	22	30	7	15	12	21	29	6	14
13	13	21	28	6	13	12	19	27	4	13	10	18	25	3
14	3	10	17	25	14	1.31	9	16	24	14	20	7	14	22
15	20	28	6	13	15	19	27	5	12	15	18	25	3	11
16	10	18	25	3	16	8	16	23	1.31	16	7	15	22	29
17	29	7	14	22	17	27	5	13	20	17	26	4	11	19
18	18	26	3	11	18	17	24	2	10	18	15	23	1.30	9
19	7	14	21	29	19	5	13	20	28	19	4	11	18	26

Gold. Num.	October.				Gold. Num.	November.				Gold. Num.	December.			
	N. M.	F. Q.	F. M.	L. Q.		N. M	F. Q.	F. M	L. Q.		N. M.	F. Q.	F. M	L. Q.
	●	☽	○	☾		●	☽	○	☾		●	☽	○	☾
1	22	30	8	15	1	21	29	6	14	1	20	28	6	13
2	12	19	26	4	2	10	18	25	3	2	10	17	25	3
3	30	8	15	23	3	28	6	13	21	3	28	6	13	21
4	19	27	4	12	4	17	25	3	10	4	17	25	3	10
5	8	16	23	1.31	5	7	14	22	29	5	6	14	21	29
6	27	5	12	20	6	26	3	11	19	6	25	3	11	18
7	16	23	1.31	8	7	14	22	29	7	7	14	21	28	6
8	5	13	19	27	8	3	11	18	26	8	3	11	18	26
9	24	2	9	17	9	22	30	8	15	9	22	29	7	15
10	13	21	28	7	10	12	19	26	4	10	11	19	26	4
11	1.31	9	16	24	11	30	8	15	23	11	29	7	14	22
12	20	28	6	13	12	19	27	4	12	12	18	26	4	11
13	10	18	25	3	13	8	16	23	1.30	13	8	16	23	30
14	29	7	14	22	14	27	5	12	20	14	27	5	12	20
15	17	25	3	10	15	26	23	1	9	15	15	23	30	8
16	6	14	21	29	16	5	13	20	27	16	5	12	20	27
17	25	3	11	18	17	24	2	9	17	17	23	1.30	9	16
18	15	23	29	7	18	13	21	28	6	18	13	21	28	6
19	3	11	18	26	19	2	9	16	23	19	1.31	9	16	24

Explanation of the characters made uſe of in the foregoing table.—N. M. ●, denotes new moon,—F. Q. ☽, firſt quarter,—F. M. ○, full moon,—L. Q. ☾, laſt quarter.

To uſe this table. Having ſound the golden number for the year required, againſt that number (in each month) is the days of the month whereon the new, full, and quarter moons fall.

It is an eaſy matter to conſtruct one of theſe tables, ſince the epacts recur with the golden numbers in the courſe of the lunar cycle, till the year of our Lord 1900.

But there are other rules for finding the change, beſide that which I have already given, which, it may not be improper to acquaint you with: Some add the number of the months from March incluſive, to the epact of the year given; if the ſum be leſs than 30 ſubtract it from 30; if greater, ſubtract it from 60, and the remainder will be the day whereon the new moon will fall. If the new moon be ſought for in the month of January or March, then nothing is to be added to the epact; if for February or April, then only 1 is to be added. Others make uſe of this rule, but with this exception, if the ſum be above 30, they take it out of 59, the remainder they account the day of the new moon. And for her age at any time, ſome to the day of the month add the epact for that year, and the months from March (including both months) together, the ſum, if under 30, is her age; if above 30, ſubtract 30 from it, the remainder is the moon's age.

N. B. If the month have but 30 days, they muſt ſubtract but 29 inſtead of 30.

To find the moon's being upon the meridian or ſouthing.—Multiply her age by 4, and divide the product by 5, the quotient will give the hours, and the remainder multiplied by 12 will give the minutes, when the moon is leſs than 15 days old; but when more than that, you muſt ſubduct 15, and work with the remainder as before.

Example for April 15, 1758.

Moon's age 7
Multiply by 4
—
Divide by 5) 28 (5 hours.
25
—
Remaind. 3
Multiply by 12
—
Product 36 Minutes.

Hence the moon will be on the meridian at 36 min. paſt 5 in the afternoon.

N. B. This will be ſerviceable to ſuch as travel in the night ſeaſon, whereby they may eſtimate the hour of the night, by judging what hours the moon wants of or is paſt the meridian; for if the moon be under 15 days old, ſhe ſouths in the afternoon, but if above 15 days old, ſhe ſouths in the morning.

To find the time of the moon's ſhining.—Multiply her age by 48, and divide the product by 60, the quotient will be the hours, and the remainder the minutes, that is, if the moon be under 15 days old; but if above, ſubtract the time of her ſhining found as above from 24 hours, the remainder will be the time of her ſhining in the morning.

EXAMPLE for April 15, 1758.

Moon's age 7
Multiply by 48

Divide by 60) 336 (5 hours.
300

Remaind. 36

So ſhe will only ſhine 5 hours and 36 minutes at that age.

To find how many ſigns and degrees the moon is departed from the ſun ſince her laſt conjunction with him, or ſince the laſt new moon.—Double the moon's age, and divide the product by 5, the quotient is the number of ſigns, and the remainder multiplied by 6 are the degrees.

EXAMPLE for April 15, 1758.

Moon's age 7
Multiply by 2

Divide by 5) 14 (2 ſigns.
10

Remaind. 4
Multiply'd by 6

Product 24 degrees.

Therefore the moon is gone from the ſun 2 ſigns and 24 degrees.

Note, The zodiac is divided into 12 equal parts, called ſigns; and each of thoſe ſigns divided again into 30 equal parts, called degrees; ſo a degree is the 360th part of the zodiac. The moon runs through the whole circle once a month.

To know the hour of the night by the moon's ſhining upon a ſun-dial.—See what the ſhadow of the moon upon the ſun-dial wants of 12, which take from the time of her coming to the ſouth, the remainder is the hour of the night; but if the ſhadow be paſt 12, add thoſe hours to the coming to the ſouth, and the ſum is the hour of the night.

EXAMPLE for January 23, 1758.—The moon is ſouth at 48 minutes paſt 4 in the morning, and I obſerving the ſhadow on a ſun-dial to fall upon the 11 o'clock hour line, required the hour of the night?

As the ſhadow falls upon the morning hour line, I take 1 hour from the moon's ſouthing, and I find it is about 48 minutes paſt 3 in the morning.

EXAMPLE II. Admit the moon is ſouth at 3 hours and 30 minutes in the afternoon, and obſerving the ſhadow of the dial to fall on the hour of 1 hour and 30 minutes, I deſire to know the true hour of the night.

OPERATION.	hour.	min.
True time time of the moon's ſouthing	7	30
Shadow paſt 12, add ———	1	30
Sum is the true hour of the night	9	0

Theſe rules being ſo plain it is needleſs to give any more examples.

To find the moon's riſing and ſetting at any time.—Before the full, add the quantity of her ſhining to the time of the ſun's ſetting, and you have the moon's ſetting; and for her riſing, add the quantity of her ſhining to the ſun's riſing, and you have the moon's riſing. But after the full, you ſubtract the length of her ſhining from the hour of ſun riſing or ſetting.

EXAMPLE for April 15, 1758.—The moon's ſhining was found to be 5 hours and 36 minutes. The ſun at that time riſes 3 minutes paſt 5, and ſets 57 minutes paſt 6.

	hour.	min.
To	6	57
Add	5	36
	12	33
Add	0	48
Hour of the moon's ſetting	1	21

N. B. The moon changed 36 minutes before 1 in the morning of the 8th of that month.—But as ſhe would be 8 days old before ſhe ſet, we muſt add 48 minutes more to the aforeſaid ſum, and it will be 21 minutes paſt 1 or ſhe ſet on the 8th day of her age.

To find the time of the moon's riſing and ſetting by the annexed table.—Seek the moon's age in the firſt or third column, and in the middle, right againſt her age, you will find the quantity of her ſhining in hours and minutes: If it is in her increaſe, ſhe ſhines ſo many hours and minutes after ſun ſet; if in her decreaſe, ſhe ſhines ſo many hours and minutes before ſun riſing.

To know the time of her ſetting: Add the hours and minutes againſt her age to the hour of ſun-ſetting, and that is the time of her ſetting: For her riſing, add the ſame to the time of ſun riſing; do thus all the increaſe. After the full, ſubtract the hours and minutes in the table from the hour of the ſun's riſing or ſetting; and if ſubtraction cannot be made, add 12, and then ſubtract, and the remainder ſhews the time of the moon's riſing or ſetting.

Moon's age increaſing.	The time ſhe ſhines. h.	m.	Moon's age decreaſing.
1	0	48	29
2	1	36	28
3	2	24	27
4	3	12	26
5	4	0	25
6	4	48	24
7	5	36	23
8	6	24	22
9	7	12	21
10	8	0	20
11	8	48	19
12	9	36	18
13	10	24	17
14	11	12	16
15	12	0	0

A

A TABLE *of the Sun's riſing every 3d Day in the Year, in the Lat. of* 54° 58′.

	ii.	v.	viii.	xi.	xiv.	xvii.	xx.	xxiii	xxvi	xxix
Jan.	8,28	8,26	8,23	8,19	8,15	8,11	8,06	8,01	7,55	7,50
Feb.	7,42	7,36	7,30	7,23	7,17	7,10	7,06	6,59	6,51	
March	6,41	6,34	6,28	6,21	6,14	6,07	6,00	5,54	5,47	5,40
April	5,32	5,25	5,18	5,12	5,05	4,58	4,52	4,46	4,40	4,34
May	4,28	4,22	4,16	4,10	4,05	4,00	3,55	3,50	3,45	3,41
June	3,37	3,35	3,32	3,30	3,28	3,27	3,27	3,27	3,28	3,29
July	3,30	3,32	3,35	3,38	3,41	3,45	3,49	3,53	3,58	4,03
Aug.	4,09	4,16	4,22	4,28	4,34	4,40	3,45	4,52	4,58	5,05
Sept.	5,13	5,20	5,27	5,33	5,40	5,44	5,52	6,00	6,07	6,13
Oct.	6,20	6,27	6,33	6,40	6,47	6,53	7,00	7,07	7,13	7,20
Nov.	7,28	7,35	7,40	7,46	7,52	7,58	8,02	8,08	8,13	8,17
Dec.	8,21	8,24	8,27	8,29	8,32	8,33	8,33	8,33	8,32	8,31

To find the ſun's ſetting, ſubtract the riſing from 12. For the length of the day, double the ſetting. For the length of the night, double the riſing.

N. B. The day is accounted with us, for payment of money, between the ſun's riſing and ſetting; but for indictments for murder, the day is accounted from midnight to midnight; and ſo likewiſe are faſting days.

To know the day of the month the ſun entereth any of the twelve ſigns, obſerve this general rule, which for common uſe may ſerve well enough, and is as follows:

R U L E.—Twice 9, twice 10, 4 twelves, 11,
Then 10, then 9, then 8 or 7.

This being Mr Thomas Street's memorial rule, and intimates that March ought to be accounted the firſt month the ſun enters.—Thus,

♈	March	9	♌	July	12	♐	November	11
♉	April	9	♍	Auguſt	12	♑	December	10
♊	May	10	♎	September	12	♒	January	9
♋	June	10	♏	October	12	♓	February	8

Which, according to the new ſtile, correſponds to

♈	March	20	♌	July	23	♐	November	22
♉	April	20	♍	Auguſt	23	♑	December	21
♊	May	21	♎	September	23	♒	January	20
♋	June	21	♏	October	23	♓	February	19

Where note, that the character

♈	is *Aries*, or the ram,	♎	is *Libra*, or the ballance,
♉	*Taurus*, or the bull,	♏	*Scorpio*, or the ſcorpion,
♊	*Gemini*, or the twins,	♐	*Sagittarius*, the archer,
♋	*Cancer*, or the crab,	♑	*Capricornus*, the goat,
♌	*Leo*, or the lion,	♒	*Aquarius*, the waterman,
♍	*Virgo*, or the virgin,	♓	*Piſces*, or the fiſhes,
	[called northern ſigns.]		[called ſouthern ſigns.]

The reaſon why the ſigns acquired theſe names will be given when I treat of the invention of the zodiac.

To find the degree of the ſun's place on any given day.

Rule. From the day of the month given (if you can) ſubtract the day of his entrance into the ſign of that month, the remainder is the degree of the ſun's place in that ſign. Or elſe when you cannot ſubtract, add 30 to the day given, and from the ſum ſubtract the day of the entrance into the ſign of that month, the remainder ſhall be the degree of his place in the ſign preceding the month given.

Example I. for March 31. I deſire to know the ſun's place.

From March 31, the day given, ſubtract the ſun's entrance ♈ March 20, the remainder 11 is the degree of the ſun's place in Aries.

Example II. for May 15. I deſire to know the ſun's place.

To May 15, the day given, add 30, the ſum is 45, from which ſubtract the ſun's entrance into ♊ May 21, the remainder is the ſun's place in ♉ 24 degrees.

To find the moon's place on any given day.

Rule. Find the ſun's place for the time given, then find what ſigns and degrees the moon has departed from the ſun, which being numbered according to the ſucceſſion of the ſigns, gives the moon's place at that time.

Example. I demand the moon's place on Jan. 24, 1758.

From January 24, the given time, take 20, the time of the ſun's entrance into Aquarius, the remainder 4 is the degrees of the ſun's place.—And finding the moon to be 15 days old at that time, which doubled, and divided by 5, quotes 6, the number of ſigns ſhe is diſtant from the ſun: So that I find ſhe is 6 ſigns and 4 degrees diſtant from the beginning of Aquarius; or, which is the ſame thing, ſhe is 6 ſigns diſtant from the ſun, which at that time is 4 degrees in Aquarius; ſo conſequently ſhe muſt be 4 degrees in Leo.

N. B. The moon's place being carefully obſerved, will greatly aſſiſt the young aſtronomer in the diſcovery of theſe ſigns.; for ſhe, like the index of a clock, will point them out one by one to a diligent obſerver, ſo that he need not apply to any other tutor.

But one thing ought to be remarked, which is the preceſſion of the equinoxes. The firſt aſtronomers who made a ſphere, took care to place the 1ſt degrees of the ſigns ♈ and ♎, ♋ and ♑, at the points of the equinoxes and ſolſtices. They had thus accounted for a long time, and were perſuaded that the ſtars which they ſaw at theſe points never left their places. Notwithſtanding, it has been by degrees perceived, that the firſt ſtar of Aries moved a degree towards the eaſt from the point of the equinox in about 72 years. And in ſhort, all the ſigns are at preſent advanced 30 degrees eaſtward, and diſtant from the points to which they gave their names; but yet theſe points retain even to this day the names of thoſe ſigns which have now left them. Tho' the ſun the 20th day of March is under the firſt degree of Piſces, yet we ſtill continue to ſay, as formerly, he enters that day into Aries. It is the ſame in proportion with the reſt of the ſigns. From hence proceeds that ſlow motion of the fixed ſtars about the poles of the ecliptic, performed in about 25,920 Julian years, which ſpace is called the Platonic or great year, (*annus magnus*); after the expiration of which, the ſtars and all ſublunary things return again to their firſt ſtate and places.

Hence alſo we have a new ſubject of reproach to aſtrologers: They attribute benign influences to Libra; a malignant impreſſion to the Scorpion; and to other ſigns ſuch effects as are conformable to the nature of the animals or objects whoſe names the ſigns bear. They pretend above all, that the whole activity of influence is felt the moment that ſuch a ſign riſes above the horizon: But this pretenſion is very idle; for when they ſay that a man is born under the dangerous aſpect of the Scorpion, it is in reality Libra which appears above the horizon. Gemini riſes when they ſay it is Cancer, and ſo of the reſt; and the error will ſtill be greater the more the ſigns advance.

The number of fixed ſtars that lie in the moon's way, according to Mr Flamſtead: Taken from the Philoſophical Tranſactions, N° 55.

In the zodiac are,

In ♈	12
♉	21
♊	21
♋	12
♌	22
♍	18
♎	12
♏	8
♐	14
♑	20
♒	16
♓	13
In all	189

Out of the zodiac are,

In Auriga	5
Ophiucus	7
Cete	3
Orion	2
Pleiades	6
In all	23

So that the moon in one revolution of her nodes paſſeth over 212 fixed ſtars.

As planets or the erratic ſtars move in the zodiac, it may not be improper to give the reader ſome rules whereby he may diſtinguiſh them from the reſt of the ſtars. Firſt, the fixed ſtars are affected with a twinkling, which is occaſioned by the agitation or tremors of the air; and therefore any opake atom floating therein, cauſes a momentary occultation of them. But the planets, tho' ſmall, are ſtill bigger than thoſe motes to the eye, and therefore are free from this twinkling, and ſhine with a conſtant and uniform light. The other criterion of a planet is its motion from one part of the heavens to another, and from thence it is called a planet, which in Greek ſignifies a wandering ſtar. All other ſtars keep the ſame diſtances conſtantly from each other.

From the foregoing rules for finding the moon's age, &c. may be deduced the following table, which I have copied from Thomas Todd's treatiſe, entitled, *Perpetuum Kalendarium Aſtronomicum*, for the benefit of ſuch as have not leiſure to calculate for themſelves. *See p.* 44, 45.

To uſe the following TABLE obſerve the following general Rule.

Having obtained the epact of the year deſired, guide your eye from the given day of the month in the left hand page ſtreight through the table, to the right hand page, till you come at the column where the ſaid epact is placed at the top, and the number ſtanding therein is the moon's age. But if you ſhould meet with N, or F, you muſt obſerve that N denotes the new moon, and F the full at that time.

EXAMPLE. Let it be required to find the moon's age on the 13th of April, 1767?

The epact for that year being nothing, or a cypher, therefore I only ſlide my finger from the 13th of April in the left hand page ſtreight through the table of months, and in the firſt column of the right hand page under 0 at the top, in the angle of meeting, I find F, which intimates that the moon is that day at full.

Again, what is the moon's age on the 13th of April, 1758?

The epact being 20, I guide my eye ſtreight from the 13th of the ſaid month to the column under 20, where, in the angle of meeting, I find 5, which denotes her to be about 5 days old at that time.

Note, The day of new or full moon in any month may be ſpeedily obtained by looking down the column of the epact for the year, for the letter N. or F. and ſliding your finger ſtreight from thence to the column of the deſired month in the left hand page, and the figure or figures ſtanding therein will ſhew you the day of the new or full moon that year.

EXAMPLE. In the year 1758, I deſire to know what day of April the moon will be at full. Under 20, the epact for the year, which ſtands in the right hand page, I look for F, then ſliding my finger ſtreight from thence into the left hand page, and in the column under April is 23, the day of the month the moon will be at full in 1758. The ſame is to be obſerved in finding the new moons.

N. B. This table is calculated according to the foregoing rules, which, as was intimated before, exhibits her age, &c. according to her mean motion, which may ſometimes differ from the true time ſome few hours, but never the ſpace of one day.

There are other perpetual tables in the aforeſaid treatiſe, ſuch as the table for finding the moon's ſign, and that of finding her riſing, &c. but they are defective through the change of the ſtile; and the reader may obſerve, that this table would have been deficient, had I not ſupplied the defect, by inſerting no leſs than 11 columns, on account of the following epacts, viz. 0, 2, 5, 8, 10, 13, 16, 19, 21, 24, 27.

His aforeſaid table of the moon's ſign is alſo very erroneous; ſo that if the calculator's exigence require, he may conſtruct a more correct one by the foregoing rules.

A Perpetual Revolutional TABLE, *ſhewing the Moon's Age, and Day of Full and New Moon, for any Time paſt, preſent, or to come, by having only the Epact for the Year deſired.*

Jan.	March	Feb. April	May	June	July	Aug.	Sept. Oct.	Nov. Dec.
1 31	30	29	28	27	26	25	23	21
2	1 31	30	29	28	27	26	24	22
3	2	1	30	29	28	27	25	23
4	3	2	1 31	30	29	28	26	24
5	4	3	2	1	30	29	27	25
6	5	4	3	2	1 31	30	28	26
7	6	5	4	3	2	1 31	29	27
8	7	6	5	4	3	2	30	28
9	8	7	6	5	4	3	1 31	29
10	9	8	7	6	5	4	2	30
11	10	9	8	7	6	5	3	1 31
12	11	10	9	8	7	6	4	2
13	12	11	10	9	8	7	5	3
14	13	12	11	10	9	8	6	4
15	14	13	12	11	10	9	7	5
16	15	14	13	12	11	10	8	6
17	16	15	14	13	12	11	9	7
18	17	16	15	14	13	12	10	8
19	18	17	16	15	14	13	11	9
20	19	18	17	16	15	14	12	10
21	20	19	18	17	16	15	13	11
22	21	20	19	18	17	16	14	12
23	22	21	20	19	18	17	15	13
24	23	22	21	20	19	18	16	14
25	24	23	22	21	20	19	17	15
26	25	24	23	22	21	20	18	16
27	26	25	24	23	22	21	19	17
28	27	26	25	24	23	22	20	18
29	28	27	26	25	24	23	21	19
30	29	28	27	26	25	24	22	20

The Epact *for the Year.*

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
☽'s ag.	☽'s ag.	☽'s ag.	☽'s ag.	☽'s ag.	☽'s ag.	☽'s ag.	☽'s ag.	☽'s ag.	☽'s ag.	☽'s ag.	☽'s ag.	☽'s ag.	☽'s ag.	☽'s ag.	☽'s ag.	☽'s ag.	☽'s ag.	☽'s ag.	☽'s ag.	☽'s ag.	☽'s ag.	☽'s ag.	☽'s ag.	☽'s ag.	☽'s ag.	☽'s ag.	☽'s ag.	☽'s ag.	☽'s ag.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	F	16	17	18	19	20	21	22	23	24	25	26	27	28	29	N
2	3	4	5	6	7	8	9	10	11	12	13	14	F	16	17	18	19	20	21	22	23	24	25	26	27	28	29	N	1
3	4	5	6	7	8	9	10	11	12	13	14	F	16	17	18	19	20	21	22	23	24	25	26	27	28	29	N	1	2
4	5	6	7	8	9	10	11	12	13	14	F	16	17	18	19	20	21	22	23	24	25	26	27	28	29	N	1	2	3
5	6	7	8	9	10	11	12	13	14	F	16	17	18	19	20	21	22	23	24	25	26	27	28	29	N	1	2	3	4
6	7	8	9	10	11	12	13	14	F	16	17	18	19	20	21	22	23	24	25	26	27	28	29	N	1	2	3	4	5
7	8	9	10	11	12	13	14	F	16	17	18	19	20	21	22	23	24	25	26	27	28	29	N	1	2	3	4	5	6
8	9	10	11	12	13	14	F	16	17	18	19	20	21	22	23	24	25	26	27	28	29	N	1	2	3	4	5	6	7
9	10	11	12	13	14	F	16	17	18	19	20	21	22	23	24	25	26	27	28	29	N	1	2	3	4	5	6	7	8
10	11	12	13	14	F	16	17	18	19	20	21	22	23	24	25	26	27	28	29	N	1	2	3	4	5	6	7	8	9
11	12	13	14	F	16	17	18	19	20	21	22	23	24	25	26	27	28	29	N	1	2	3	4	5	6	7	8	9	10
12	13	14	F	16	17	18	19	20	21	22	23	24	25	26	27	28	29	N	1	2	3	4	5	6	7	8	9	10	11
13	14	F	16	17	18	19	20	21	22	23	24	25	26	27	28	29	N	1	2	3	4	5	6	7	8	9	10	11	12
14	F	16	17	18	19	20	21	22	23	24	25	26	27	28	29	N	1	2	3	4	5	6	7	8	9	10	11	12	13
F	16	17	18	19	20	21	22	23	24	25	26	27	28	29	N	1	2	3	4	5	6	7	8	9	10	11	12	13	14
16	17	18	19	20	21	22	23	24	25	26	27	28	29	N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	F
17	18	19	20	21	22	23	24	25	26	27	28	29	N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	F	16
18	19	20	21	22	23	24	25	26	27	28	29	N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	F	16	17
19	20	21	22	23	24	25	26	27	28	29	N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	F	16	17	18
20	21	22	23	24	25	26	27	28	29	N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	F	16	17	18	19
21	22	23	24	25	26	27	28	29	N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	F	16	17	18	19	20
22	23	24	25	26	27	28	29	N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	F	16	17	18	19	20	21
23	24	25	26	27	28	29	N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	F	16	17	18	19	20	21	22
24	25	26	27	28	29	N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	F	16	17	18	19	20	21	22	23
25	26	27	28	29	N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	F	16	17	18	19	20	21	22	23	24
26	27	28	29	N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	F	16	17	18	19	20	21	22	23	24	25
27	28	29	N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	F	16	17	18	19	20	21	22	23	24	25	26
28	29	N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	F	16	17	18	19	20	21	22	23	24	25	26	27
29	N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	F	16	17	18	19	20	21	22	23	24	25	26	27	28
N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	F	16	17	18	19	20	21	22	23	24	25	26	27	28	29

I ſhall conclude my diſcourſe of the moon with ſome pertinent remarks. And,

Firſt, In regard to her phaſes, it muſt be obſerved, that one half of her body is always enlightned by the ſun's rays, and the other half dark; and her enlightned hemiſphere is always oppoſite to the ſun; alſo the light which ſhe caſts to our earth is only the ſun's light reflected from her ſurface.

This is exceeding eaſy to conceive; for every one knows, that a ball enlightened by the ſun, or a candle, can receive the immediate light only upon one hemiſphere. It flies off at the verge of the illuminated part, and continues to move directly forwards in the air without touching the oppoſite ſide, which muſt conſequently remain in the dark.

At conjunction or change, the moon is in the ſame part of the heavens with the ſun, and her enlightned hemiſphere being towards him, the obſcure part will be towards the earth, ſhe will become inviſible without being annihilated, ſince no object is viſible but by the rays of light reflected from it.

But if it ſhould happen in or near that place where the moon's orbit croſſes the ſun's, (or more properly the earth's) it occaſions that phænomenon which we call an eclipſe of the ſun, becauſe her enlightened part is towards him, and her dark ſide towards the earth, ſhe will intercept the ſun's rays from us. This may be plainly evinced by placing a bowl of water on the ground, whereby you may diſcover the moon's dark body ſliding over the ſun's diſk at that time. You may alſo perceive it by viewing the ſun through a piece of common window glaſs ſmoaked or dulled over the flame of a candle.

Now the moon moving every day eaſtward from the ſun about 12 degrees, it is plain for a day or two that the moon will ſhortly ſet after the ſun with her illuminated hemiſphere towards him, which is ſo far weſt of us that we can only ſee a border of her light: And for this reaſon we always ſee the creſcent or new moon in the weſtern part of our hemiſphere, and the extremities of the creſcent will be on the left hand pointing to the eaſt. And as ſhe approaches more eaſterly, this ſtreak of light appears ſtill broader.

Here it may not be improper to take notice of another phænomenon at the creſcent or horning of the moon, and even in a ſolar eclipſe, we ſometimes ſee, when the horizon is clear, a reddiſh dirty-coloured light on her obſcure hemiſphere. This light is occaſioned by the earth; for when the moon is in conjunction with the ſun, the earth to her will be in oppoſition; for when the moon is new to us, the earth is at full to the lunar inhabitants; and the light of the earth being about 15 times greater than that of the moon, and the moon ſo little as not to obſcure above a 20th part of the earth, the light of the earth may eaſily be ſuppoſed to render her a little viſible, even in ſolar eclipſes, and much more in the creſcent after the ſun is ſet. Hence this faint light which appears like kindled aſhes on the dark part of the moon's body, is no more than the ſun's rays reflected from the earth's ſurface.

At the end of ſeven days and a half, or thereabouts, after the conjunction, ſhe will be in her quadrature, or ſquare, to the ſun, becauſe ſhe will come to the meridian at ſun-ſetting; her enlightened hemiſphere being ſtill towards the ſun, we can only view half the illuminated part; and tho' we cannot ſo eaſily diſcover half the obſcure part, yet we are certain that it takes up the reſt of the diſk; we then ſay ſhe is a quarter old, or half full: And ſtill as ſhe approaches more towards the eaſt, the illuminated part becomes more conſpicuous to us, till at laſt ſhe arrives at the greateſt diſtance from the ſun in about 15 days; at which time ſhe will be advanced to the eaſtern part of the horizon about ſun-ſetting, and will come to the meridian about midnight; then ſhe will be diametrically oppoſite to the ſun, and ſo will expoſe all her illuminated hemiſphere to our view, and ſo we ſay ſhe is at full, becauſe we could not till now perceive all her enlightened part.

If the moon ſhould happen at this time to be in the ecliptic, ſhe will be eclipſed; for the earth intervening betwixt the ſun and her, will obſtruct the ſun's rays from falling on her body; becauſe at this time they will all three be in a right line, ſo that the earth's ſhadow will obſcure the moon's face or diſk. And thus you ſee the reaſon of an eclipſe of the moon, which will be better underſtood when I treat of the aſtronomical part.

She having thus finiſhed half of her circuit, and ſteering her courſe ſtill in the ſame direction, ſhe will now begin to approach the ſun again; and her illuminated hemiſphere, which was formerly weſt of us, begins to get eaſtward of us, and ſhe begins to ſhine more in the morning, and riſe later in the night. Hence we may plainly diſcover the ſun's light forſake her weſtern limb, extending itſelf as much upon the other ſide that is not directed to the earth. When ſhe begins to riſe about midnight, ſhe will be got into the laſt quarter, and ſhew her face inverted to what it was in the firſt quarter. At length ſhe begins to riſe only ſome few hours before the ſun, and the extremities of the illuminated part will paſs ſucceſſively over the anterior diſk towards the left, till the moon be ready to paſs again between the ſun and the earth, permits its inhabitants to ſee only a thin border of her enlightened face, which is turned from our eyes; and the ſun appearing under this circumſtance a little to the left of the moon, with regard to the ſpectator, the creſcent or border of light will extend its horns towards the right, and on the weſtern ſide. This is a palpable theory, for ſuch as have not yet conſidered the reaſon of her phaſes.

I ſhall now explain the phænomenon of the harveſt moon; and in order to this, we need only conſider that when the ſun is in the beginning of Aries, the full moon on that day muſt be in the beginning of Libra; and ſince when the ſun ſets, or the moon riſes, on that day, thoſe equinoctial points will be in the horizon, and the ecliptic will then be leaſt of all inclined thereto, the part or arch which the moon deſcribes in one day, viz. 13 degrees, will take up about an hour and a quarter aſcending above the horizon; and, therefore ſo long will be the time after ſun-ſet the next night, before the moon will riſe. But at the oppoſite time of the year, when the ſun is in the autumnal, and the full moon in the vernal equinox, the ecliptic will, when the ſun is ſetting, have the greateſt inclination to the horizon; and therefore 13 degrees will, in this caſe, ſoon aſcend, viz. in about a quarter of an hour, and ſo long after ſun-ſet will the moon riſe the next day after the full. Whence, at this time of the year there is much more moon-light than in the ſpring: And hence this autumnal full moon came to be called the harveſt moon, the hunter's or ſhepherd's moon. All which may be clearly ſhewn on the celeſtial globe.

CHAP.

C H A P. VII.

To find Eaſter Day, and other Moveable Feaſts for ever; with Remarks on the ſame.

ALtho' I have already ſhewn how to find Eaſter day perpetually, I ſhall here propoſe another method of finding it by the two following rules.

RULE I. To find Eaſter limit, or the day of the paſchal full moon, counting from March the 1ſt incluſive:—Add 6 to the epact, and if this ſum exceeds 30, take 30 from it; then from 50 ſubtract this remainder, and what is left will be the limit. If the ſum of the epact added to 6 does not amount to 30, it muſt be ſubtracted from 50, and the remainder is the limit required, which is never to exceed 49, nor fall ſhort of 21.

RULE II. From the limit and dominical letter, to find Eaſter day.—Add 4 to the dominical letter, accounting A 1, B 2, C 3, &c. ſubtract this ſum from the limit, and the remainder from the next higher number which contains 7, without any remainder: Laſtly, add this remainder to the limit, and their ſum will give the number of days from the 1ſt of March to Eaſter day, both incluſive.

Thus, for inſtance, to find Eaſter day for the year 1758.—Firſt, find the epact 20, which added to 6, gives 26; and as this ſum does not amount to 30, it muſt be ſubtracted from 50, and the remainder 24 is the limit. Then adding 4 to 1, the number of the dominical letter A, ſubtract this ſum, viz. 5, from the limit 24, and the remainder 19 from 21, (the next ſuperior number that contains 7 a certain number of times without any remainder) and there remains 2, which being added to the limit 24, gives 26, for the number of days from the 1ſt of March to Eaſter-day, both incluſive, which muſt of conſequence fall on the 26th of March.

Here follows the OPERATION at length.

Epact	20	From	50	Dominical letter A, or	1
	6	Take	26		4
	—		—		—
Sum	26	Reſts	24	Sum	5

From	24	From	21
Take	5	Take	19
	—		—
Reſts	19	Reſts	2 which added to 24,

gives 26, as before.

Having found Eaſter, the other moveable feaſts are found by the verſes following:

The Sunday next the feaſt of St Andrew,
The Advent of our bleſſed lord doth ſhew.
Th' unſtated feaſt Septuageſima,
Nine weeks 'fore Eaſter ſtands by paſchal law.
The Sunday Sexageſima we call,
Does juſt eight weeks 'fore Eaſter-Sunday fall.
Next *Quinquageſima, by ſeven weeks
Precedes, and †Quadrageſima by ſix.

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* Shrove Sunday. † Firſt Lent Sunday.

Five after Eaſter we Rogation find,
And Five days thence ‡Aſcenſion is aſſign'd.
The ſeventh from Eaſter is §Whitſunday feaſt,
On Trinity day, at eight weeks end, we reſt.

Note, This rule once got by heart is preferable to any table, becauſe it may be retained in mind when the table is abſent.

A Table of the remarkable Days and fixed Feaſts.

Jan	1	Circum. or new year's day
	6	Epiph. or 12th day
	13	St Hilary
	25	Converſion of St Paul
	30	K. Charles I. mart. 1648
Feb.	2	Purif. Virgin Mary
	14	Valentine
	24	St Matthias
Mar.	17	St Patrick
	25	Ann. V. M. or Lady-day
Apr.	23	St George
	25	St Mark Evangeliſt
May	1	St Philip and James
June	11	St Barnabas
	24	St John Baptiſt
	29	St Peter and Paul
July	15	St Swithin
	22	Magdalen
July	25	St James Apoſtle
Aug.	1	Lammas
	24	St Bartholomew Apoſt.
Sept.	21	St Matthew Apoſtle
	29	St Michael Archangel
Oct.	18	St Luke Evangeliſt
	25	Criſpin
	28	St Simon and Jude
Nov.	1	All-Saints
	5	Gunpowder treaſon
	11	St Martin
	30	St Andrew Apoſtle
Dec.	21	St Thomas Apoſtle
	25	Chriſt's nativity
	26	St Stephen
	27	St John Evangeliſt
	28	Innocents

‡ Holy Thurſday. § Deſcent of the Holy Ghoſt.

A TABLE *of moveable Feaſts from* 1758 *to* 1800, *N. S.*

Years of Chriſt	Gol. N.	Dom Let. N. S.	Dom Let. O. S.	Septuageſima Sunday	Aſh-Wedneſday	Eaſter Sunday	Rogat. Sunday	Aſcenſion day
1758	11	A	D	Jan. 22	Feb. 8	Mar. 26	Ap. 30	May 14
1759	12	G	C	Feb. 11	28	Ap. 15	May 20	24
B 1760	13	F E	B A	3	20	6	11	15
1761	14	D	G	Jan. 18	4	Mar. 22	Ap. 26	Ap. 30
1762	15	C	F	Feb. 7	24	Ap. 11	May 16	May 2
1763	16	B	E	Jan. 30	16	3	8	12
B 1764	17	A G	D C	Feb. 19	Mar. 7	22	27	31
1765	18	F	B	3	Feb. 20	7	12	16
1766	19	E	A	Jan. 20	12	Mar. 30	4	8
1767	1	D	G	Feb. 15	Mar. 4	Ap. 19	24	28
B 1768	2	C B	F E	Jan. 31	Feb. 17	Apr. 3	May 8	May 12
1769	3	A	D	22	8	Mar. 20	Ap. 30	4
1770	4	G	C	Feb. 11	28	Ap. 15	May 20	24
1771	5	F	B	Jan. 27	13	Mar. 31	5	9
B 1772	6	E D	A G	Feb. 16	Mar. 4	Ap. 19	24	28
1773	7	C	F	7	Feb. 24	11	16	20
1774	8	B	E	Jan. 30	16	3	8	12
1775	9	A	D	Feb. 12	Mar. 1	16	21	25
B 1776	10	G F	C B	4	Feb. 21	7	12	16
1777	11	E	A	Jan. 20	12	Mar. 30	4	8
1798	12	D	G	Feb. 15	Mar. 4	Ap. 19	May 24	May 28
1779	13	C	F	Jan. 31	Feb. 17	4	9	13
B 1780	14	B A	E D	23	9	Mar. 26	Ap. 30	4
1781	15	G	C	Feb. 11	28	Ap. 15	May 20	24
1782	16	F	B	Jan. 27	13	Mar. 31	5	9
1783	17	E	A	Feb. 16	Mar. 5	Ap. 20	25	29
B 1784	18	D C	G F	8	Feb. 25	11	16	20
1785	19	B	E	Jan. 23	9	Mar. 27	1	5
1786	1	A	D	Feb. 12	Mar. 1	Ap. 16	21	25
1787	2	G	C	4	Feb. 21	8	13	17
B 1788	3	F E	B A	Jan. 20	Feb. 6	Mar. 23	Ap. 27	May 1
1789	4	D	G	Feb. 8	25	Ap. 12	May 17	21
1790	5	C	F	Jan. 31	17	4	9	13
1791	6	B	E	Feb. 20	Mar. 9	24	29	June 2
B 1792	7	A G	D C	5	Feb. 22	8	13	May 17
1793	8	F	B	Jan. 27	13	Mar. 31	5	9
1794	9	E	A	Feb. 16	Mar. 5	Ap. 20	25	29
1795	10	D	G	1	Feb. 18	5	10	14
B 1796	11	C B	F E	Jan. 24	10	Mar. 27	1	5
1797	12	A	D	Feb. 12	Mar. 1	Ap. 16	21	25
1798	13	G	C	Feb. 4	Feb. 21	Apr. 8	May 13	May 17
1799	14	F	B	Jan. 20	6	Mar. 24	Ap. 28	2
1800	15	E	A G	Feb. 9	26	Ap. 13	May 18	22

The Table continued.

Whit-ſunday	Advent Sunday	Epact.
May 11	Dec. 3	20
June 3	2	1
May 25	No. 30	12
10	29	23
30	28	4
22	27	15
Jun. 10	Dec. 2	26
May 26	1	7
18	No. 30	18
June 7	29	0
May 22	No. 27	11
14	Dec. 3	22
June 3	2	3
May 19	1	14
June 7	No. 29	25
May 30	28	6
22	27	17
June 4	Dec. 3	28
May 26	1	9
18	No. 30	20
June 7	No. 29	1
May 23	28	12
14	Dec. 3	23
June 5	2	4
May 19	1	15
June 8	No. 30	26
May 30	28	7
15	27	18
June 4	Dec. 3	0
May 27	2	11
May 11	No. 30	22
31	29	3
23	28	14
Jun. 12	27	25
May 27	Dec. 2	6
19	1	17
June 8	No. 30	28
May 24	29	9
15	27	20
June 4	Dec. 3	1
May 27	Dec. 2	12
12	1	23
June 1	No. 30	4

REMARKS on the foregoing Feaſts, &c.

The Paſchal, or Eaſter term, being the oldeſt, it therefore claims pre-eminence, as well for this reaſon as others hereafter given.

It commenced in the days of Moſes, and reign of Pharoah, king of Egypt, when God cut off all the firſt born in the land of Egypt. Exod. xii. 3. But all the children of Iſrael eſcaped by the blood of the paſchal lamb; which feaſt God commanded the Iſraelites to commemorate. Now we are hereby to underſtand this as a tyype of that immaculate lamb which was ſlain for the ſalvation of our ſouls. Hence our Saviour is frequently in ſcripture called the lamb of God; for it was at this very ſeaſon he ſuffered, viz. at the feaſt of the paſſover. If the Jews held this in great veneration for the preſervation of their lives, in how much greater ought we, who are chriſtians, to hold it for the ſalvation of our ſouls?—Let us conſider we are only ſojourners in this world, as they were in the land of Egypt; wherefore let us omit no opportunity of commemorating this new paſſover charitably one with another, I mean the holy communion which was inſtituted by Chriſt himſelf.

Septuageſima, Sexageſima, Quinquageſima, and Quadrageſima Sundays, ſo called from being 70, 60, 50, and 40 days from Eaſter.

Shrove-Tueſday is ſo called from an old Engliſh word *ſhrive*, which ſignifies to confeſs; and therefore it was formerly called Shrive-Tueſday, becauſe people at this time uſed to go to ſhrive, that is, to make a confeſſion before Lent. —The word Lent, comes from an old Saxon word *Lente*, which ſignifies the ſpring of the year. And which word has always been uſed to ſignify that ſpace of time which was ſet apart for faſting before Eaſter, becauſe it is in the ſpring. It is uſed in the church to commemorate our Saviour's faſting in the wilderneſs.

The Romans abſtain from eating fleſh this ſeaſon, and any dripping liquor or broth from any fleſh; from an old ſaying, that *you may as well eat the devil as the broth he is boiled in.*

Paſſion-Sunday, ſo called, to put people in mind of the feſtival of the paſſion of Chriſt.

Palm-Sunday, in remembrance of the palm branches ſtrewed in the way when Chriſt came this day to Jeruſalem.

Manday-Thurſday, from Mandat-Thurſday, from the firſt word of Chriſt's charge on this Thurſday to his diſciples of loving one another, *Mandatum novum do vobis*, &c. I give you a new command or mandate, that you love one another.

Good Friday, ſo called particularly (above all other days in the year) by the name of Good, it being that ſuperlatively good day on which that eminently good and great work of man's redemption was conſummated.

Eaſter Day, is ſo called from the eaſt, in which the ſun riſes, becauſe on this day Chriſt did riſe from the dead; ſo Eaſter is as it were Eaſt day, that is, the riſing day.

Low Sunday, is ſo called from its being the Sunday that falls immediately next after, or next lower than Eaſter. So when Eaſter falls at the end of March 'tis a high Lent, but when it falls late in April it is called a low Lent.

The Monday, Tueſday, and Wedneſday before Aſcenſion day, are called Rogation days, from Rogo, to aſk, or beg, becauſe proceſſions were then made in the fields, to beg a bleſſing on the fruits of the earth.

Whitſunday, ſo called from the firſt Chriſtians wearing white cloaths this day as a mark of innocence.—I ſhall now proceed to the fixed feaſts.

January 1, Chriſt was circumciſed by the law of Moſes, which is therefore called the Circumciſion, but more commonly New-year's day, becauſe our year commences on it.

February 2, The Purification of the Virgin Mary, but commonly called Candlemas day, from the Romans bleſſing of candles at the maſs on this day.

March 1, St David's day, an eminent biſhop of Wales, from corrupting of whoſe name into Taffy, 'tis that Welchmen are ſometimes called Taffies.

May 1, St Philip and James, apoſtles. The milkmaids dancing on this day is the remnant of a Heathen cuſtom of dancing round poles adorned with flowers, (and ſo called May-poles) in honour of their goddeſs Flora.

July 15, which correſponds to the 26th, St Swithin, biſhop of Wincheſter, died Ann. dom. 860, called by ſome Weeping Swithin, becauſe they ſuppoſe that two particular ſtars riſe with the ſun, which generally bring rain with them, and therefore ſay that if it rains on St Swithin day, it will rain more or leſs 40 days after. But this has often been found falſe, and ſo is not to be depended on.

On the 19th of the ſaid month, which agrees with the 30th, they alſo ſay the canicular or Dog-days begin; from the dog ſtar Sirius, riſing with the ſun, which brings hot weather with it, which they ſay end about the 29th of Auguſt, which accords with the 9th of September. But I probably may give better reaſons for ſuch kind of weather afterwards.

Auguſt 1, Lamb-Maſs day, ſo called from the country people's offering in former times a ſheered lamb at maſs, that their ſheep might not die with cold after ſheering.

November 1, All-ſaints, a day formerly ſet apart to beg the interceſſion of all the ſaints together. It is called All-hallows day, the word Hallow being an old Engliſh word to ſanctify, bleſs, or pronounce holy, as ſtill appears in the divine prayer, "Our father, &c." where it is daily ſaid, "Hallowed be thy name," that is, holy be thy name.

The 4 weeks before Chriſtmas is called Advent, from the Latin word *Adventus*, which ſignifies coming, to put people in mind of the coming of Chriſt.

December 25, the nativity of our Saviour Chriſt, called Chriſtmas day, from the ſolemn maſs at midnight, in remembrance of Chriſt's being born (according to hiſtorians) at 12 o'clock at night.

The 28th day, the children ſlain in Bethlehem by Herod, thinking to ſlay Chriſt amongſt them. It is ſometimes called Childermas day.

Ember weeks, are thoſe weeks in which the Ember days fall. They were of great antiquity in the church in the primitive times, and are four in number; and were therefore called by the antient fathers, *Quatuor anni tempora*, the four cardinal ſeaſons on which the circles of the year turn. They are the Wedneſdays, Fridays, and Saturdays next after Quadrageſima Sunday, after Whitſunday, after Holy-Rood day, Sept. 14, and after St Lucy's day, Dec. 13. They were at firſt ordained for quarterly ſeaſons of devotion; wherein, as the firſt fruits of every ſeaſon, the antient Chriſtians put up their prayers and ſupplications to Almighty God, that thereby the whole year, and every of its four parts might be bleſſed; and uſed to eat nothing till eventide, and then only a cake baked under the embers, or aſhes, which they called ember bread. Theſe Ember weeks are chiefly taken notice of on account of the ordination of prieſts and deacons, becauſe the canon now appoints the Sundays next ſucceeding the Ember weeks for ſolemn times of ordination; though biſhops, if they pleaſe, may ordain on any Sunday or holiday.—Dr Harris, in his Lexicon Technicum ſays, in the laws of King Alfred, C. 39, and in thoſe of Canute, C. 16, they are called Ymbren, *i. e.* cicular days, from whence they are corrupted into Ember days; and agrees with this diſcourſe in other reſpects, tho' he takes no notice of their eating Ember bread.

Note, September 14, was uſed to be called Holy-Rood day, becauſe the croſs on which Chriſt ſuffered was regained in 644, by Heraclius the emperor, in a victory over Coſroes, king of Perſia, that had had it 14 years. This emperor on this day carried it on his ſhoulders, and there ſet it up, and exalted it with great ſolemnity; and therefore called Holy-Rood day, from an old Saxon word Rood, which ſignifies a croſs.

But there is another feſtival on the 3d of May, called Crouchmas day. The croſs on which Chriſt ſuffered on was found A. D. 326, being ſearched for by order of Q. Helen, mother to Conſtantine the Great, having been hid, and buried by the Heathens 180 years, being ſo called from the maſs on this day: The word Crouch being an old Engliſh word for Croſs. And there is now a place in London called ſtill Crouched Friars, where formerly was a houſe of religious men, ſo called from their wearing a croſs upon their habits.

A TABLE *of all the moveable Feaſts for ever, according to the Fal of Eaſter, New Stile.*

Eaſter Sunday	Septuagesima Sunday	Aſh-Wedn.	Rogat. Sunday	Aſcenſion Sunday	Whit-Sunday	Advent Sunday
Mar. 22	Jan. 18	Feb. 4	Apr. 26	Apr. 30	May 10	No. 29
23	19	5	27	May 1	11	30
24	20	6	28	2	12	Dec. 1
25	21	7	29	3	13	2
26	22	8	30	4	14	3
27	23	9	May 1	5	15	No. 27
28	24	10	2	6	16	28
29	25	11	3	7	17	29
30	26	12	4	8	18	30
31	27	13	5	9	19	Dec. 1
April 1	28	14	6	10	20	2
2	29	15	7	11	21	3
3	30	16	8	12	22	No. 27
4	31	17	9	13	23	28
5	Feb. 1	18	10	14	24	29
6	2	19	11	15	25	30
7	3	20	12	16	26	Dec. 1
8	4	21	13	17	27	2
9	5	22	14	18	28	3
10	6	23	15	19	29	No. 27
11	7	24	16	20	30	28
12	8	25	17	21	31	29
13	9	26	18	22	June 1	30
14	10	27	19	23	2	Dec. 1
15	11	28	20	24	3	2
16	12	Mar. 1	21	25	4	3
17	13	2	22	26	5	No. 27
18	14	3	23	27	6	28
19	15	4	24	28	7	29
20	16	5	25	29	8	30
21	17	6	26	30	9	Dec. 1
22	18	7	27	31	10	2
23	19	8	28	June 1	11	3
24	20	9	29	2	12	No. 27
25	21	10	30	3	13	28

N. B. When any of the feaſts fall in January or February in leap-years, ſuch feaſts muſt be taken a day later than by the table.

Of

OF TERMS and RETURNS.

A TABLE *of moveable Terms for ever, according to the fall of Eaſter.*

Eaſter Term begins	Ends	Trinit. Term begins	Ends
Apr. 8	May 4	May 22	Jun. 10
9	5	23	11
10	6	24	12
11	7	25	13
12	8	26	14
13	9	27	15
14	10	28	16
15	11	29	17
16	12	30	18
17	13	31	19
18	14	June 1	20
19	15	2	21
20	16	3	22
21	17	4	23
22	18	5	24
23	19	6	25
24	20	7	26
25	21	8	27
26	22	9	28
27	23	10	29
28	24	11	30
29	25	12	July 1
30	26	13	2
May 1	27	14	3
2	28	15	4
3	29		5
4	30	17	6
5	31	18	7
6	June 1	19	8
7	2	20	9
8	3	21	10
9	4	22	11
10	5	23	12
11	6	24	13
12	7	25	14

Note, Eaſter term begins 17 days, and ends 43 days after Eaſter. Trinity term begins 5 days, and ends 24 days after Trinity. Therefore Eaſter Term continues 27, and Trinity 20, incluſive.

HILARY TERM begins January 23, ends February 12.

1 Return — Jan. 20
2 Return — 27
3 Return — Feb. 3
4 Return — 9

EASTER TERM.

1 Return 14 days
2 Return 21
3 Return 28
4 Return 35
} from Eaſter excluſive.
5 Return on morrow of Aſcenſion

TRINITY TERM.

1 Return, morrow of holy Trinity
2 Return 7 days
3 Return 14
4 Return 21
} from holy Trinity excluſive.

MICHAELMAS TERM begins Nov. 6, ends Nov. 28.

1 Return — Nov. 3
2 Return — 12
3 Return — 18
4 Return — 25

Terms begin three days ſooner at Doctors Commons than at Weſtminſter.

N. B. The eſſoin day is regularly the firſt day of every term, tho' the fourth day after is alſo allowed by way of indulgence.

Eſſoin, in law, an excuſe for a perſon ſummoned to appear and anſwer to an action, on account of ſickneſs or other juſt cauſe of his abſence. It is a kind of imparlance or craving of longer time, and obtains in real, perſonal, and mixed actions. There are divers eſſoins, as *de ultra mare*, when the defendant is beyond the ſea, whereby he is allowed forty days: In an expedition to the holy land, a year and a day: Infirmity, called common eſſoin, when he is ſick in his bed: And, laſtly, in the king's ſervice.

Ox-

OXFORD and CAMBRIDGE TERMS.

Hillary term begins January 14, and ends the day before Palm-Sunday.

Eaſter term begins Wedneſday after the 1ſt Sunday after Eaſter, and ends Thurſday before Whitſuntide.

Trinity term begins Wedneſday after Trinity Sunday, and ends the Friday after the commencement.

Michaelmas term begins Oct. 10, and ends Dec. 17.

The Iriſh terms are the ſame as Weſtminſter, except the Michaelmas term, which begins October 13, adjourns to November 3, and from thence to the 6th. It hath ſeven returns.

The SCOTCH TERMS.

Candlemas term begins January 23, ends February 12.

Whitſuntide term begins May 25, ends June 1.

Lammas term begins July 20, ends Auguſt 8.

Martinmas term begins November 3, ends November 29.

N. B. If the beginning or end of any of theſe terms fall on Sunday. then the beginning or ending of the ſame is on Monday next following.

Obſervations on TERMS and RETURNS.

Term is uſed for that time wherein our courts of juſtice are open: In oppoſition to which, the reſt of the year is called vacation.—It has been held that courts do not ſit except in term time, as to giving judgments, &c. and in every term there are four days thus diſtinguiſhed; that is, the eſſoin day, the day of exceptions, the day of return of writs, and day of appearance. On the eſſoin day, the term is ſaid to begin when one judge ſits in each of the courts of Weſtminſter, in order to take and enter eſſoins: But it is not till three days afterwards that all the judges ſit for the diſpatch of buſineſs.—There are alſo different returns in different terms, ſome having more, ſome fewer: And as in the king's bench all returns are to be made on ſome particular day of the week in each term, care muſt be taken not to make the writs out of that court returnable on a non-judicial day; ſuch as Sundays and All-ſaints in Michaelmas term, the Purification in Hilary, the Aſcenſion in Eaſter, and Midſummerday, except it ſhould fall on the firſt day of Trinity term.

The two learning vacations in the four inns of court at London, viz. the two Temples, Lincoln's-Inn, and Gray's, begin the firſt day in Lent, and the firſt after Lammas-day, and continue three weeks and three days.

C H A P. VIII.

Uſeful Tables and Rules for Traders.

A PERPETUAL TABLE.

G	F	E	D	C	B	A
Sund.	*Mon.*	*Tueſ.*	*Wedn.*	*Thur.*	*Frid.*	*Satur*
April	*Sept.*	*June*	*Feb.*	*Aug.*	*May*	*Jan.*
July	*Dec.*	*June*	*Mar.* *Nov.*	*Aug.*	*May*	*Oct.*
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31	00	00	00	00

To uſe this Table.

Firſt, knowing the dominical letter for the year required, find it in the uppermoſt line, and underneath it is the day of the week to be ſuch a day of the month.

Example. A being the dominical letter for the year 1758, underneath A we find Saturday; therefore the firſt Saturday in January will be the 7th day of the month; and the firſt Saturday in February will be the 4th of that month for that year, &c. Now if the firſt Saturday in January be the 7th day of the month, it is eaſy to conceive that the 2d will be the 14th, which is placed in the ſame column under 7; the 3d, the 21ſt, &c.——*Note*, In leap-years there are two dominical letters; the firſt ſerves for January and February only, and the other for the remaining part of the year. Having once intelligence what day of the month ſuch a day of the week falls on according to this table, it will not be difficult to know on what day of the week any year begins.

Here follows another Table much like the above.

Jan. *Oct.*	*Feb.* *Mar.* *Nov.*	*Apr.* *July*	*May*	*June*	*Aug.*	*Sept.* *Dec.*
1	5	2	7	4	6	3
8	12	9	14	11	13	10
15	19	16	21	18	20	17
22	26	23	28	25	27	24
29	00	30	00	00	00	31

This table is of excellent uſe to know what day of the month any day of the week ſhall happen on for ever.

Note, On which day of the week the year begins, the figures under each month ſhews that thoſe days of the ſaid months, happens on the ſame day of the week.

Example. If the firſt day of January happens on Sunday, then the 5th of February, March, &c. ſhall happen on Sunday: And this holds good in all common Years. But if the year be biſſextile, then after the month of February the figures under each month happens on the ſame day of the week with the 2d of January.

Theſe tables are perpetual monitors, quickly directing any perſon to any day of the month he ſhall require.

Here follows an eaſy rule to know how many days are contained in each month:

Thirty days hath September,
April, June, and November;
February hath twenty-eight alone,
All the reſt have thirty-one;
But when leap-year comes the time,
Then February has twenty-nine.

CHAP. IX.

Of Calends, Nones, and Ides.

THE Romans called the firſt day of every month calends, from the Greek word *caleo*, to call; becauſe anciently counting their months by the motion of the moon, there was a prieſt appointed to obſerve the times of the new moon, who, having ſeen it, gave notice to the preſident over the ſacrifices, and he called the people together, and declared unto them how they muſt reckon the days until the nones, pronouncing five times the word *caleo*, if the nones did happen on the fifth day; or ſeven times, if they happened on the ſeventh day of the month.

The nones of a month are the next days after the calends, which is the firſt day.

In March, May, July, and October, the Romans counted ſix days of the nones, but all the reſt of the months but four.

They had this name probably becauſe they were always 9 days incluſive, from the firſt of the nones to the ides, *i. e.* reckoning both thoſe days.

Ides of a month were the days after the nones were out. They commonly fell out on the 13th of every month, except in March, May, July, and October, (which they called full months, as all others were called hollow) for then they were on the 15th, becauſe in thoſe months the nones were on the 7th, and they always follow eight days after the nones.

Here follows the Roman method of accounting them.

RULE.—— The firſt day of each month they calends call,
May, March, October, July, ſix nones fall,
In the other eight months, four; eight ides in all.

But the method whereby they accounted them was backward, or in a retrograde order.

EXAMPLE. The ides fall on the 13th of January, the 14th day is called the 19th of the calends of February, the 15th is called the 18th, &c. till you come to the 31ſt, which is called *pridic calendas*, or the day before the calends. In like manner the 2d day of February is called the 4th of the nones, the 3d is the 3d, then the 4th is Pr. N. and the 5th will be the nones. Again, the 6th will be the 8th of the ides, the 7th the 7th of the ides, the 8th the 6th, &c. till you come to the 11th, which is called *tertio idus*, and the 12th, *pridic idus*.

There are ſome common prayer-books belonging to the pariſh church of Great Salkeld, whoſe calendars contain columns of this method of computation.

This method of reckoning time is ſtill retained in the chancery of Rome, and the calendar of the breviary.

A PERPETUAL DIARY, *ſhewing by the Dominical Letter, the Day of the Week correſpondent to the Day of the Month in any Year paſt, preſent, or to come, either according to the New or Old Stile.*

Months.	Dominical letters.						
January, October	A	B	C	D	E	F	G
Feb. March, Nov.	D	E	F	G	A	B	C
April, July	G	A	B	C	D	E	F
May	B	C	D	E	F	G	A
June	E	F	G	A	B	C	D
Auguſt,	C	D	E	F	G	A	B
Sept. Dec.	F	G	A	B	C	D	E
Days of the month correſpondent to the 7 week day columns in order of ſucceſſion, from the Sunday column.	1	2	3	4	5	6	7
	8	9	10	11	12	13	14
	15	16	17	18	19	20	21
	22	23	24	25	26	27	28
	29	30	31				

Example I.

To find on what day of the week the 1ſt of March happens 1758, N. S. the dominical letter being A for that year.

To the right of the month March, find the dominical letter A, under which at the bottom is the Sunday column, wherein ſtand all the Sundays in that month, viz. 5, 12, 19, 26; ſo that the 1ſt of March is on a Wedneſday. For the next columns to the right in order ſhew all the Mondays, Tueſdays, Wedneſdays, &c. by which the week day to any month day of any year is diſcovered at ſight ſooner than by any other method whatſoever.

Note, Sunday column is under the dominical letter for the year; which letter is to be ſought for to the right of the month.

Example II.

To find on what day of the week the 16th of January was on, 1701.— Now the rule to find the dominical letter for any year of our Lord, O. S. is comprized in the following verſe.

Divide the year, its fourth, and 4, by ſeven,
What's left, ſubtract from 7, the letter's given.

The given year 1701
Its 4th part, omitting fractions 425
Laſtly, the number 4

Divide by 7) 2130 (304

Remainder 2 which taken from 7
leaves

leaves 5; ſo the dominical letter is the 5th letter of the alphabet, counting A 1, B 2, &c. to 5, which will be E.

To the right of the month January, find the dominical letter E, under which is the Sunday column, wherein ſtand 5, 12, 19, 26, all the Sundays in that month; conſequently January 16 ſtands in the Thurſday column, ſo that January 16, 1701, O. S. is on a Thurſday required.

To reduce the new to the old ſtile, and the contrary.—From the hundreds of Chriſt take their fourth, adding two, and the days will remain betwixt old ſtile and new.

A PERPETUAL TABLE, *ſhewing what Day of the Week begins any Month for ever.*

Months.	A	B	C	D	E	F	G
January	Sund.	Satur.	Friday	Thur.	Wed.	Tueſ.	Mond.
February	Wedn.	Tueſ.	Mond.	Sund.	Satur.	Friday	Thur.
March	Wedn.	Tueſ.	Mond.	Sund.	Satur.	Friday	Thur.
April	Saturd.	Friday	Thur.	Wed.	Tueſ.	Mond.	Sund.
May	Mond.	Sund.	Satur.	Friday	Thur.	Wed.	Tueſ.
June	Thur.	Wed.	Tueſ.	Mond	Sund.	Satur.	Friday
July	Satur.	Friday	Thur.	Wed.	Tueſ.	Mond.	Sund.
Auguſt	Tueſ.	Mond.	Sund.	Satur.	Friday	Thur.	Wed.
September	Friday	Thur.	Wed.	Tueſ.	Mond.	Sund.	Satur.
October	Sund.	Satur.	Friday	Thur.	Wed.	Tueſ.	Mond.
November	Wed.	Tueſ.	Mond.	Sund.	Satur.	Friday	Thur.
December	Friday	Thur.	Wed.	Tueſ.	Mond.	Sund.	Satur.

This table is very plain; for having the dominical letter for the given year, find that on the head, and guide your eye down from it till you come right againſt the month, and there is the name of the day of the week that begins that month.

PART

P A R T II.

Containing an Account of the Solar Syſtem, explaining the Laws and Means whereby the Planets are preſerved in their Orbits, with inconteſtible Proofs of their moving round the Sun; wonderfully diſplaying the Wiſdom and Power of the great Creator of the Univerſe. Of Eclipſes, and how to predict them perpetually. A Synopſis of Comets, ſhewing how to predict the Appearance of four remarkable Comets. A Synopſis of Aſtronomy, &c. Invention of the Zodiac. Rules for the Equation of Time. Celeſtial Appearances, &c.

C H A P. I.

Laws of Motion. Orbits of Planets. An Account of the Solar Syſtem, &c.

BEfore I enter on the ſubject of aſtronomy, I think it neceſſary to premiſe Sir Iſaac Newton's laws of motion, in order to prepare the reader's notions for his better conceiving what he will find inſerted therein.

LAW I. Every body preſerves its own preſent ſtate, whether it be that of reſt or uniform direct motion; unleſs it is compelled by ſome force impreſſed to change that ſtate.

A body at reſt would remain ſo for ever by its own inactivity. It is alſo evident from the merely paſſive nature of matter, which makes it naturally as impoſſible for a body of itſelf to ſtop its own motion once begun, as it is to move itſelf originally. If it were not for the reſiſtance of the air and its own gravity, a ſtone would fly perpetually when once caſt from us.

Note, That all motion is of itſelf rectilinear, or in a right line.

LAW II. The change of motion is proportionable to the moving force impreſſed; and is always according to the direction of that right line with which that motion is impreſſed.

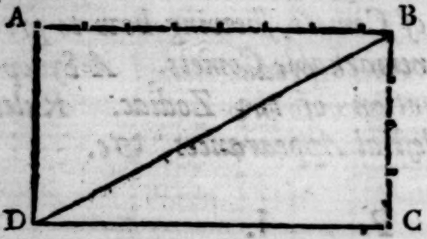
If any force generates any motion, a double force will generate a double one; a treble, a treble one; and this whether the force be impreſſed all at once, or ſucceſſively.

LAW III. Action and re-action are always equal, and contrary one to another.

Whatever preſſes or draws another thing, is equally preſt or drawn by it, but in the contrary way.

When a horſe draws a ſtone tied to a rope, the horſe will equally be drawn back to the ſtone. For the rope which is diſtended on both ſides, will, with the ſame endeavour of relaxing itſelf, draw the horſe to the ſtone, as it doth the ſtone to the horſe: and will ſo much hinder the progreſs of the one as it forwards the progreſs of the other. If you preſs upon the table with your hand, the reſiſtance or re-action is equal to the preſſure, and your hand is as much preſt as the table. If one body ſtrike upon another, and thereby produce any change in its motion, it does by the reſiſtance or re-action of the other body undergo the like change itſelf, tho' to the contrary part; and always loſes as much motion as it produces, imparts, or communicates.

By theſe laws it will be eaſy to prove that a body will deſcribe the diagonal of a parallelogram, by two forces conjoined, in the ſame time that it would deſcribe the ſides by each force ſeparately. This is that famous propoſition of Sir Iſaac Newton, upon which his whole ſyſtem depends.



That it may be more eaſily underſtood, ſuppoſe a body B to repreſent a ſhip at ſea, and that it is drove by the wind in the direction of the line B A, with ſuch a force as would carry it uniformly 8 miles in an hour from B to A. Then ſuppoſe a ſtream or current of water running in the direction B C, with ſuch a force as would carry the ſhip 4 miles in an hour from B to C; by theſe two forces acting together, the ſhip will deſcribe the diagonal B D, and at the end of an hour it will be found at the point D. For the force B A will not hinder the body's approaching the line C D, drawn parallel to it; neither will the force B C hinder the body from approaching the line A D, therefore the body will be found at the end of the given time in the point D.

If both the forces act upon a body in ſuch a manner as to cauſe it to move uniformly, the diagonal deſcribed will be a right line; but if one of the forces act in ſuch a manner as to cauſe the body move faſter and faſter as it goes forwards, then the line deſcribed will be a curve: For when a ſtone is caſt into the air, its projectile force is continually diminiſhed by the reſiſtance of that medium; and as this force weakens, the force of gravity grows more powerful, which cauſes it to deſcend faſter and faſter, and makes it fall in a curve line to the earth.

N. B. By this propoſition we may diſcover what kind of a line any body in motion will deſcribe by two forces, in conjunction, which being maturely conſidered will greatly aſſiſt you in apprehending what will be related of the motions of celeſtial bodies.

Beſides the aforementioned property of paſſiveneſs in matter, it is endowed with another, known by the name of attraction.

Attraction is that force by which bodies are drawn, impelled, or in ſome manner made to move towards one another.

Thus gravity, which is proportionable to the quantity of matter in any body, comes under the denomination of attraction; of this we have daily inſtances in the falling of bodies to the earth.

Now we are to underſtand that the huge bodies of the planets muſt of conſequence be endowed with this property, and it ſeems natural to ſuppoſe that by this property they muſt tend ſomewhere.

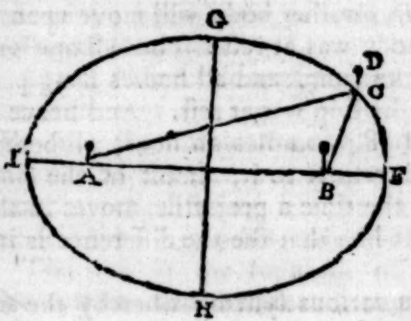
But the omnipotent and omniſcient Creator of the univerſe, at the creation ſubjected all the properties of matter to certain laws, which are always inviolably kept: And there being the ſame propenſity in the planetary ſyſtem which is among other magnetic bodies, ſo that by their gravity they muſt have a mutual tendency one towards another, which is called the centripetal force, becauſe they gravitate one towards another, as towards a center or point.

But there is another force which is always equal and proportionable to this, which is called the centrifugal force, whereby they endeavour to recede or fly from each other; for it was intimated in Sir Iſaac's firſt law, that all motion is of itſelf rectilinear, which I ſhall demonſtrate in the following inſtance.

Suppoſe a man wheels a ſtone about in a fling, ſo long as it remains therein it participates with the motion of the hand, which is circular; but ſlipping out of the fling it is not now carried forward in its former circle, or in any circle at all, but in a tangent of a former circle, that is, in a right line from the periphery of the ſaid circle: But the force of gravity, compounded with the projectile force, is the reaſon why it deſcribes a parabolic line in falling to the ground, otherwiſe it would fly perpetually in a right line, as was obſerved before.

From the very nature of each of theſe two forces it is eaſy to conceive how the planets are preſerved in their orbits; for as the centripetal force draws them towards each other, the centrifugal force prevents them; and as by their curviliner motion they endeavour to fly from each other, the centripetal force obſtructs them; and thus they harmoniouſly chime by each other, diſplaying moſt beautifully the wonderful mechaniſm of the great Creator of the univerſe, which may not unaptly be called the muſic of the ſpheres.

It muſt be obſerved that the orbits of all the planets are not exactly circular but elliptical, having the ſun in their common focus. But the elliptic orbit of the earth, by the action of the moon, is ſenſibly diſfigured; as alſo the orbit of Saturn, by the action of Jupiter, when they are conjunction. For it is evident by Sir Iſaac's 3d law, that the moon and the earth muſt have a mutual tendency towards each other; and tho' the earth, whoſe attraction is ſuperior to the moon's, can compel the moon to accompany her round the ſun, yet ſhe is ſo affected by the moon's daily wheeling round her, as to be diverted from her own proper direction, and ſo occaſion the above irregularities in her orbit.



Each of the privary planets moves round the ſun in a line which forms an ellipſis, like the annexed figure, which I will here ſhew you how to deſcribe.

Fix upon any plane two pins, as at A B, to theſe tie a ſtring A C B ſomewhat longer than their diſtance from one another; then apply a third pin D in the double of the thread, ſo as to hold it ſtrained; and in that manner carrying this pin about, the point of it will deſcribe an ellipſis. If through the points A B the right line I A B F be drawn, and terminated in the points I and F, this is the longeſt line that can be drawn within the figure, and is called the greater axis of the ellipſis. The line G H, drawn perpendicular to the axis I F, ſo as to paſs through the middle of it, is called the leſſer axis. The two points A and B are called focuſſes. Now each primary planet moves round the ſun in a line of this kind, the place of the ſun being in one of the focuſſes. Suppoſe A to be the place of the ſun, then I is the point wherein the planet will be neareſt to the ſun, and at F it will be the moſt remote. The point I is called the perihelion of the planet, and F the aphelion. In G and H the planet is ſaid to be in its middle or mean diſtance, becauſe the diſtance A G or A H is truly the middle between A I the leaſt, and A F the greateſt diſtance.

Here note, that the ſun is ſeated upon the lower focus of the ellipſis in the ſyſtem of the primary planets, and the earth upon the lower focus in the moon's ſyſtem.

N. B. The diſtanee between the center of the ellipſis and the focus is called its eccentricity.

It remains only to ſay a word or two concerning abſolute and relative motions. Abſolute motion is when one body moves with reſpect to another that is at reſt; ſo relative motion is the motion of a body with reſpect to another that moves at the ſame time.

Nothing is more obvious and plain, than that ſeveral bodies may retain the ſame poſition with reſpect to each other, and ſo be relatively at reſt, whilſt at the ſame time, abſolutely ſpeaking, they are all of them moved: As when a ſhip is under ſail, the ſeveral parts of her loading will be at reſt with reſpect to one another, yet they are all really in motion along with the ſhip; yea, we cannot poſſibly be ſure that any one thing we know of is abſolutely ſpeaking at reſt; for there may ſtill be ſome body vaſtly diſtant, but truly quieſcent, with reſpect to which, any body we imagine to be at reſt does really change its poſition. Whenever the whole is abſolutely moved, the parts, tho' relatively at reſt, do each of them partake of this abſolute motion: And by reaſon of this, any part has a conſtant diſpoſition and a ſufficient force to proceed with the ſame degree of celerity, tho' it ſhould be ſeparated from the reſt, or tho' the reſt ſhould ſtop on a ſudden, and ceaſe from their motion: And this appears more eſpecially in a circular motion. If a circular plane, or a ſpherical body, move round its axis, tho' the parts of it may retain the ſame poſition with reſpect to each other, yet by partaking of the abſolute motion, there is in each of them a perpetual diſpoſition or conatus to recede from the center or axis: And the greater the celerity, the ſtronger is this attempt or conatus. But if a body moves in a right line, another body will move upon it it in the ſame manner as tho' the firſt body was at reſt: Thus all motions upon the deck of a ſhip under ſail are the ſame, and all bodies hang perpendicular in the ſame manner as tho' the ſhip was at reſt. And hence it is, that the earth moving at the rate of 58,000 miles an hour, all bodies on the ſurface of the earth move with reſpect to it, almoſt in the ſame manner as tho' it was reſt; for during the time a projectile moves in the air, the earth moves ſo nearly in a right line that the the difference is inconſiderable.

I ſhall not at this time enumerate the various ſyſtems whereby the ancients have endeavoured to account for the motions of the planets, ſince that of Copernicus is now univerſally received, but proceed to give an account of it with inconteſtible proofs of its truth.

N. B. It may not be improper to premiſe that the Ptolemaic ſyſtem ſuppoſes all the celeſtial bodies to move round the earth a their common centre

The Copernican ſyſtem or hypotheſis, is that ſyſtem of the world wherein the ſun is ſuppoſed at reſt in the center, and the planets with the earth to move in ellipſis round him. The ſun and ſtars are here ſuppoſed to be at reſt, and the diurnal motion they appear to have from eaſt to weſt is imputed to the earth's motion from weſt to eaſt, round its axis. This ſyſtem was received of old by Philolaus, Ariſtarchus, and Pythagoras, from which laſt it had the name of Pythagoric. It was alſo held by Archimedes; but after him it became neglected, and even forgotten for many ages, till it was revived by Nicholas Copernicus, a native of Thorn in Poliſh Pruſſia, about the year 1500, and from him named the Copernican ſyſtem.

According to this hypotheſis, the ſun is ſuppoſed very near the center of gravity of the whole ſyſtem, and in the common focus of every one of the planetary orbits. Next him Mercury performs his revolution round him; next Mercury is the orbit of Venus; and next to Venus, our earth, with its attendant or ſecondary the moon, performing a joint courſe, and in their revolution, meaſuring out the annual period; next the earth is Mars, the firſt of the ſuperior planets; next him Jupiter, and his 4 ſatellites or moons; and laſt of all Saturn, and his 5 attendants.

Theſe and the comets are the conſtituent parts of the ſolar ſyſtem, which is now received and approved as the only true one, for the reaſons following.

Firſt, It is more reaſonable to ſuppoſe that the earth moves round the ſun, than that the huge bodies of the planets, the ſtupendous body of the ſun, and the immenſe firmament of ſtars, ſhould all move round the inconſiderable body of the earth every 24 hours.

But that harmony which, upon this ſuppoſition runs through the whole ſolar ſyſtem, wonderfully confirms this hypotheſis, viz. that the motions of all the planets, both primary and ſecondary, are governed and regulated by one and the ſame law; which is, that the ſquares of the periodical times of the primary planets, are to each other as the cubes of their diſtances from the ſun: And likewiſe the ſquares of the periodical times of the ſecondaries of any primary, are to each other, as the cubes of their diſtances from that primary.

Now the moon, which in the Copernican ſyſtem is a ſecondary of the earth, in the other hypotheſis is a primary one; and ſo the rule cannot take place, becauſe the periodical time conſidered as a primary one, does not agree therewith.

Again, this ſingle conſideration Mr Whiſton thinks enough to eſtabliſh the motion of the earth for ever, viz. if the earth does not move round the ſun, the ſun muſt move with the moon round the earth. Now the diſtance of the ſun to that of the moon, being as 10,000 to 46, and the moon's period being leſs than 28 days, the ſun's period would be found no leſs than 242 years, whereas in fact it is but found one year.

The ſun is the fountain of light and heat, which irradiates all the ſyſtem, and therefore it ought to be placed in the center, ſo that the planets may at all times have it in an uniform and equable manner.

For if the earth be in the center, and the ſun and planets revolve about, the planets would then, like the comets, be ſcorched with heat when neareſt the ſun, and frozen with cold in their aphelium, or greateſt diſtance, which is not to be ſuppoſed.

But happily we are able to give not only reaſons, but demonſtrative proofs, that the ſun does poſſeſs the center of the ſyſtem, and that the planets move about it at the diſtance and in the order aſſigned.

The firſt is, that Mercury and Venus are ever obſerved to have two conjunctions with the ſun, but no oppoſition, which could not happen unleſs the orbits of theſe planets lay within the orbit of the earth.

The ſecond is, that Mars, Jupiter, and Saturn, have each their conjunctions and oppoſitions to the ſun alternate and ſucceſſively, which could not be unleſs their orbits were exterior to the orbit of the earth.

In the third place, the greateſt elongation or diſtance of Mercury from the ſun, is about 20 degrees, and that of Venus 47 degrees; which anſwers exactly to their diſtance in this ſyſtem, though in the Ptolemean ſyſtem they might, and would ſometimes, be ſeen 180 degrees from the ſun, viz. in oppoſition to him.

Fourthly, in this diſpoſition of the planets, they will all of them be ſometimes much nearer the earth than at others; the conſequence of which is, that their brightneſs and ſplendor, and alſo their apparent diameters, will be proportionably greater at one time than another; and this we obſerve to be true every day; thus the apparent diameter of Venus when greateſt is 66 ſeconds, but when leaſt not more than 9 ſeconds and a half; of Mars, when greateſt, it is 21 ſeconds, but when leaſt, no more than two and a half; whereas by the Ptolemean hypotheſis they ought always to be equal.

The fifth is, that when the planets are viewed with a good teleſcope, they appear with different phaſes, or with different parts of their bodies enlightened. Galilus was the firſt who took notice of theſe phænomena, which are of great importance in eſtabliſhing this theory; for Venus is ſometimes new, then horned, and afterwards dichotomiſed, then gibbous, afterwards full, and ſo increaſes and decreaſes her light in the ſame manner as the moon, and as the Copernican ſyſtem requires.

The ſixth is, that the planets do all of them ſometimes appear direct in motion, ſometimes retrograde, and at other times ſtationary; thus Venus, as ſhe paſſes from her greateſt elongation weſtward, to her greateſt elongation eaſtward, will appear direct in motion, but retrograde as ſhe paſſes from the latter to the former; and when ſhe is in thoſe points of the greateſt diſtance from the ſun, ſhe ſeems for ſome time ſtationary: All which is neceſſary upon the Copernican hypotheſis, but cannot happen in any other.

The ſeventh is, that the bodies of Mercury and Venus, in their lower conjunctions, are hid behind the ſun's body, and in the upper conjunctions, are ſeen to paſs over the ſun's body or diſk, in the form of a black round ſpot, which is neceſſary in the Copernican ſyſtem, but impoſſible in the Ptolemean ſyſtem.

The eighth and laſt is, that the times in which theſe conjunctions, oppoſitions, ſtations, and retrogradations of the planets happen, are not ſuch as they would be, were the earth at reſt in its orbit, but preciſely ſuch as would happen were the earth to move, and all the planets in the periods aſſigned them; and therefore this and no other can be the true ſyſtem of the world.

Having, I hope, ſufficiently proved the truth of this hypotheſis, notwithſtanding the objections of thoſe who argue to the contrary, from the literal expreſſion of Joſhua; do we not all of us ſay, that the ſun riſes and ſets, when we know theſe phænomena are occaſioned by the revolution of the earth round its own axis? Did not Moſes ſay, God created two great lights, when in reality, one of them, viz. the moon, has no inherent light but what ſhe receives from the ſun? And why might not Joſhua ſay, ſun ſtand thou ſtill, &c. ſince it would appear to do ſo, tho'he knew this phænomenon was to be effected in a different manner.

If we do not admit of allegories in ſcripture, I am afraid we ſhall greatly injure both it and our underſtandings. Does it not ſay in one place that the earth is ſupported by pillars; and in another, that he, viz. God, has hung the earth upon nothing? How ſhall we reconcile theſe contradictious paragraphs, but by ſuppoſing one of them metaphorical.

So I hope that philoſophy, inſtead of being repugnant to holy writ, is ſerviceable to us, in putting a right conſtruction on the figurative expreſſions of our anceſtors; and therefore highly neceſſary to be underſtood.

Since this new philoſophy has taken place, let us contemplate on the omnipotence and omniſcience of the great Creator of the univerſe. How beautiful and noble muſt the plan of our ſyſtem appear to us, when we conſider how the earth and the reſt of the planets perpetually wheel paſt each other, without danger of either obſtructing each other, or deviating from their orbits: So well it may be ſaid he has hung the earth upon nothing, and yet it is ſupported by ſuch pillars as will perpetually keep it from falling.

Perpetual motion, which has been in vain attempted by poor earthly mortals, is here expoſed compleat to all beholders. But as he who formed this plan is in every reſpect infinite, ſo we are not capable of conceiving the greatneſs of his power, nor the profoundneſs of his wiſdom.

The ſtars which are at ſuch immenſe diſtances from us, and appear ſo little, are all ſuppoſed to be ſuns enlightening other planetary worlds as our ſun doth ours, and the reſt of this planetary ſyſtem. Hence our ſun which is of ſuch huge dimenſions as to be a million times greater than our earth, will but appear as a point or a ſtar to the inhabitants of other ſyſtems; and as their ſuns appear to us ſo little that the leaſt atom eclipſes them, and cauſes a momentary occultation of them, which is demonſtrable from their twinkling with the agitation or tremours of the air. How immenſe muſt ſpace be! But how infinite muſt the Almighty be in in all his Works! God, he knows what kind of beings are the ſeveral inhabitants of theſe worlds; but we are certain from what we have already diſcovered, that he has created nothing in vain. Tho' Jupiter and Saturn are of ſuch remote ſituations as to acquire but a ſmall portion of the ſolar light and heat, yet they have each of them ſeveral moons to illuminate their dark parts.

The aſtronomers have remarked by the direction of the ſpots which move upon the diſk of Jupiter, that the axis of this planet is perpendicular to the ecliptic, and that this globe makes its revolution in 10 hours.— They have then an uniform ſeaſon, their days always equal, five hours of night and five of day, while ours are of 24, and our ſeaſons always vary alternately. Their years are not ours; 12 of our years make but ſo many months with them. Every thing changes then in different ſpheres. If Jupiter has four moons, it is to give it light in the night-time. But to what purpoſe this light if that planet is not inhabited. The planets therefore muſt be inhabitable worlds: And if the ſtars ſhine like a ſun with a genuine light, it is evidently becauſe they give light to other planets. We could certainly err if we ſhould imagine theſe lamps were created only for our uſe.

Altho' the teleſcope has diſcovered wonders in the heavens, the microſcope has acquainted us with his miracles in miniature; there is amply diſplayed his wonderful ſkill, or matchleſs mechaniſm, in the organizing of animalcules, above four million times leſs than the ſmalleſt viſible grain of ſand. Is not this ſurpriſing, when we conſider that ſuch creatures muſt have heads, hearts, veins, arteries, and nerves, and how inconceivable ſmall muſt the particles of their blood and animal ſpirits be! In ſhort, by calculations made upon reaſonable ſuppoſitions, we find they are ſo much leſs than a grain of ſand, as a grain of ſand is leſs than the globe of the earth; and yet they are ſo much greater than the particles of light, that they would ſeem in compariſon to them to be vaſt mountains.

Hence his exquiſite workmanſhip loudly proclaims him the king of glory, from the greateſt to the ſmalleſt part of his creation: His mercy is extended to every individual, and every living creature is preſerved by this bleſſing.

Let us not therefore vainly imagine that becauſe there is a multiplicity of worlds that God is regardleſs of this, I hope we have but too evident proofs to the contrary, both by His own ſon, and the œconomy which is preſerved among us; but let us praiſe him for the benefits we daily receive at his hands, and for the wonders he has ſhewn us, although but through a glaſs darkly, and pray that we may continue in his favour, that we may plainly behold the fullneſs of his glory in a future ſtate.

The ſpacious firmament on high,
With all the blue etherial ſky,
And ſpangled heavens, a ſhining frame,
Their great original proclaim.
Th' unwearied ſun, from day to day,
Does his creator's power diſplay;
And publiſhes to every land
The work of an almighty hand.
'Soon as the evening ſhades prevail,
The moon takes up the wond'rous tale,
And nightly to the liſt'ning earth
Repeats the ſtory of her birth:
Whilſt all the ſtars that round her burn,
And all the planets in their turn,
Confirm the tidings as they roll,
And ſpread the truth from pole to pole.
What tho' in ſolemn ſilence all
Move round the dark terreſtrial ball;*
What tho' no real voice nor ſound,
Amidſt their radiant orbs be found;
In reaſon's ear they all rejoice,
And utter forth a glorious voice;
For ever ſinging as they ſhine,
The hand that made us is divine.

ADDISON.

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* Move round, *i. e.* appear to move round the dark terreſtrial ball.

CHAP. II.

Of Eclipſes; teaching how to calculate when they will happen in either Sun or Moon perpetually.

AN eclipſe is a deprivation of light.—The eclipſe of the ſun (or truly the earth) is cauſed by the interpoſition of the moon's dark body between the ſun and our ſight, (as was intimated in my theory) and can never happen but at the new moon, when the ſun and moon are leſs than 18 degrees from the moon's nodes, *i. e.* theſe points where the moon's orbit cuts or croſſes the earth's; and by reaſon of the nearneſs of the moon to the earth, and the ſudden change in parallax, the ſame ſolar eclipſe ſhall be total to one part of the earth, to another partial, and to another inhabitant no eclipſe at all.

The moon's eclipſe is real and univerſal wherever ſhe is viſible herſelf; and is cauſed by the interpoſition of the earth between the ſun and moon, and this can never happen but at the full moon, within leſs than 12 degrees of her nodes; for the moon being an opake body, borrowing all her light from the ſun, is then deprived of that borrowed light, and ſo is eclipſed.

There can never happen more than ſix nor leſs than two eclipſes in one year, and when two, they are both of the ſun.

N. B. Some aſtronomers imagine there may in ſome years be ſeven eclipſes, but the defect of one of them would prove ſo ſmall as to be not worth minding.

Note, The moon's orbit interſects the ecliptic in two oppoſite points, called nodes, making an angle therewith of 4 degrees, 59 minutes, 35 ſeconds, in conjunction, and in oppoſition to the ſun; but in the quadratures, of 4 degrees, 17 minutes, 20 ſeconds. She is always eclipſed at full within 12 degrees of her nodes.

Now the reaſon why there happens an eclipſe of either ſun or moon when either of them are within the aforeſaid limits, is, becauſe at that time the ſum of half the diameters of the ſun and moon, or the earth's ſhadow and moon, are greater than the neareſt diſtance of their orbits, meaſured from theſe parts where both their centers paſſed; therefore the greater this difference is, the nearer they are the nodes, and conſequently the greater will the eclipſes be. But it muſt be obſerved, tho' the ſum of half the diameters of the earth's ſhadow and moon be greater than the ſum of the other two, yet with reſpect to the viſible latitude of the moon, the ſum of half the diameters of the ſun and moon is greater than the former, in regard to her true latitude; and therefore the limits of a ſolar eclipſe exceed thoſe of a lunar one. So the limits of the moon's eclipſe are 12 degrees, 2 min. 9 ſec. and her utmoſt latitude 62 min. 25 ſec. that is, if her diſtance from either node at the full moon be more than 12 deg. 2 min. 9 ſec. her latitude will exceed 62 minutes, 25 ſeconds; therefore there can be no eclipſe at that time: And the limits or boundaries of the ſun's eclipſes are, 18 deg. 20 min. 8 ſec. and the latitude of the moon then 1 deg. 34 min. 16 ſec. Theſe are the greateſt limits. But there are yet two other extreams which are called the leaſt limits, that is, if the diſtance from the nodes be ſuch, it is poſſible there may at that time be no eclipſe; and they are theſe,

Leaſt limits of	moon	10°,	19′	17″.	Lat.	53′	41″,
	ſun	16,	35	5		85	32

The cauſe of theſe two extreams of the limits, is the different diſtances of the ſun and moon from the earth at different times.

When the ſolar limit is leaſt, the ſun takes up about 28 days in paſſing over it; and therefore it is poſſible there may be no eclipſe of the ſun that node, becauſe between new moon and new moon is about 29 days and a half; and if the moon ſhould change immediately before the ſun entered this limit, the ſun might poſſibly get out of it before ſhe changed again; but this chance is ſo very great, that it was never known to happen, I believe. But when this limit is greateſt, the ſun takes up 32 days before he gets clear of it. And it ſometimes happens there are two ſolar eclipſes during the ſun's ſtay in that limit: But theſe twin eclipſes are very ſmall, and almoſt always to us inviſible. Hence we may conclude that in every ſolar limit there is one eclipſe very certain, and ſometimes two when the limit is greateſt.

Again, when the lunar limit is leaſt, the earth's ſhadow paſſeth it in 19 days, and when greateſt, in 24 days; and ſince from full moon to full moon there is 29 days and a half if the full moon ſhould happen in the beginning of the limit, before the moon could again return to the ſaid node the ſhadow would be paſt the other extream point of the ſaid limit, and ſo there would be no eclipſe of the moon in ſuch a caſe that node, even when the limit is greateſt of all. Therefore it is evident there cannot happen two lunar eclipſes together in the ſame node, when the limit is greateſt. So that upon the whole we may conclude, there can be but one eclipſe of the moon within the lunar limits, and ſometimes none at all. —In ſome years it happens there are no lunar eclipſes at all; and the reaſon is evident from what I have already ſaid.

Again, we are to obſerve that both ſolar and lunar eclipſes happen at the ſame time of the year, for the new moon which obſcures the ſun in the ſolar limit, is herſelf eclipſed by the ſhadow of the earth at the lunar limit when ſhe is next at full.

Laſtly, the nodes which are in oppoſite points of the orbit, change their nature in the ſpace of half a year, and that which is now the ſolar node will then become the lunar, and the lunar node that now is will become the ſolar node in the next ecliptic ſeaſon. But it happens to be not quite half a year, becauſe the ſun for inſtance may be eclipſed at the end of one limit, and at the beginning of the next ſolar limit, and this happened in the years 1732 and 1733, the ſun being eclipſed Dec. 6, 1732, and again on the 2d of May, 1733, in which time there intervened not above 147 days, which is ſhort of half a year by 35 days. Yea, the ſun may leave one limit and arrive to the next in about four months and a half; as in the year 1740, the ſun was eclipſed Jan. 17, and again in June 12; and another reaſon for this is, the nodes are not fixed but move in a retrograde manner, ſo that the diſtant node is carried towards the ſun, and they meet near ten days ſooner than if the nodes were fixed. Now I hope every conſiderate perſon will eaſily conceive (from what has been ſaid) the reaſon why in ſome years there happens more eclipſes than in others, and why they happen at ſuch and ſuch intervals and ſeaſons of the year. I ſhall only remark to you that in the years wherein ſix eclipſes happen there are generally two of the ſun and one of the moon in each ecliptic ſeaſon: But it ſometimes happens there are three ecliptic ſeaſons, as in the year 1740, when the luminaries came three times within the ecliptic limits, and each of them ſuffered an eclipſe each time.

The nodes or points where the moon croſſes the ecliptic are called the dragon's head and tail. The moon croſſes the ecliptic at the dragon's head when ſhe is entering that part of her orbit which inclines northward from the ecliptic; and ſhe enters the dragon's tail when ſhe is entering that part of her orbit which inclines ſouthward from the ecliptic. The former is called the aſcending node, and is charactered thus ☊, and the latter the deſcending node, and charactered thus ☋.

As to duration, every total eclipſe holds longer than any partial one: And as ſome partial eclipſes are of longer duration than others, ſo ſome total eclipſes are of longer duration than others. Such total eclipſes as are of the longeſt duration happen when the moon is in a node, and are called central eclipſes; becauſe, as the moon paſſes through that ſection of the cone of the earth's ſhadow which meets with the orbit of the moon the center of the moon paſſes exactly through the center of the ſaid ſection or ſhadow.

The ſhadow of the earth where the moon paſſes through it is about 5900 miles in diameter, which is almoſt three times the diameter of the moon, which ſhe ſometimes paſſes in 3½ hours, and ſometimes more; and the time of total darkneſs is generally 1½ hour, when the eclipſe is greateſt.

The dark ſhadow of the moon in a ſolar eclipſe, when at a mean, takes up the compaſs of about 150 miles, and when greateſt, it extends to 220 miles.

But the penumbral ſhadow is no leſs than about 4937 miles over at a mean; and when greateſt, it takes in about 600 miles more; ſo that all people living within the extent of near 5000 miles will ſee the ſun eclipſed more or leſs.

The duration of ſolar eclipſes is different, according as their middle happens, about ſix in the morning or evening, or about noon, or at any intermediate time. If it happens about ſix o'clock morning or evening, the diurnal motion then neither much conſpires with, nor oppoſes the proper motion of the center of the ſhadow: And the duration is almoſt the ſame as it would be if the earth had no diurnal motion at all. If that happens about noon, the diurnal motion moſt of all conſpires with that proper motion of the center, and makes the duration of the eclipſe the longeſt poſſible. If it happens in the intermediate times, the diurnal motion in a leſs degree conſpires with the other motion, and makes the duration of a mean quantity between that of other caſes: But if it happens conſiderably before ſix o'clock in the morning or after ſix in the evening, the diurnal motion is backward, and ſhortens that duration proportionably.

The velocity of the motion of the center of the ſhadow is unequal, not only on account of the difference of the moon's motion at the beginning and ending of the entire eclipſe, which indeed is very inconſiderable, but chiefly by reaſon of the difference of the obliquity of the horizon all the way of its paſſage.

The motion of the center of the ſhadow of the moon in eclipſes of the ſun is nearly right-lined.

The dimenſions of the penumbra, or entire eclipſe, and the extent of the total ſhadow of the earth, are continually different according to the different elevations of the ſun and moon above any particular horizon.

The figure of the entire penumbra or general eclipſe, and of the umbra or total darkneſs, as they appear upon every country, on account of the different obliquity of every horizon, is different, and will make ovals or ellipſis of different ſpecies perpetually; and in the vaſt penumbra it will be an oval, being the interſection of a conical and ſpherical ſurface; but in the ſmaller umbra or total darkneſs, which is confined to a much narrower compaſs, it very nearly approaches to the interſection of a conic ſurface, with a plane which is a true ellipſis.

The ſpecies of that ellipſis depends on the ſame altitude above the horizon at the time of total darkneſs, as does the poſition of the longer axis on the azimuth of the ſun at the ſame time. This oval when the ſun is of a conſiderable altitude is almoſt an exact one; but when the ſun is near the horizon it will be very long, and ſo leſs exact, becauſe the ſpherical ſurface of the earth is at a diſtance more remote from a plane.

The perpendicular breadth of the ſhadow is neither that of the longer nor of the ſhorter axis of the cone of the ſhadow, but that of the two longeſt perpendiculars drawn from the tangents parallel to the diameter, along which the direction of the motion is.

There are univerſally conſidered, more ſolar than lunar eclipſes, (as was proved before) but there are more of the moon in any one particular place; for ſince the earth's diſk is greater than the diſk of its ſhadow ſeen at the moon, it muſt needs be that the penumbra of the moon ſhall fall oftener into the broader diſk of the earth while the ſun is eclipſed, than the narrower moon can into the narrower diſk of the earth's ſhadow when ſhe is eclipſed. But ſince the eclipſes of the moon will be all obſervable in the ſame place, whereas ſuch of the ſun only will be viſible any where, as happen when the moon is interpoſed between that particular place and the ſun. 'Tis eaſily ſeen that in particular places lunar eclipſes muſt be moſt frequent.

Total eclipſes of the ſun are very rare, ſo that if you conſider them with regard to any particular place, you will hardly have above two or three in the compaſs of an hundred years: The reaſon of which is, that the vertex or point of the conical ſhadow of the moon's body, doth fall beyond the earth's ſurface, and ſometimes doth not quite reach it. Nor is that ſtrange when we take notice, that the moon's apparent diameter doth ſo little exceed that of the ſun, that it cannot totally cover or obſcure it, but only in ſome very rare total and central eclipſes; nor in every central one neither, for if an eclipſe happens when the ſun is in his perigeum and the moon is in her apogeum, the apparent diameter of the ſun will exceed the lunar one, and ſo the eclipſe will appear annular, or the ſhadow of the moon will be invironed with a ring of light all round about it.

It is ſuppoſed by ſome that the moon is never eclipſed by the very ſhadow of the earth itſelf, but only by that of the earth's atmoſphere. This was a propoſition perfectly unknown to the antients, but is ſufficiently apparent and manifeſt, from the conſideration of refraction. For theſe rays of light which are next the earth, enter into its atmoſphere and then go out of it again: But while they do thus paſs out of a rarer medium into a denſer, they muſt by the known laws of refraction tend towards the perpendicular; nor can it be otherwiſe when they go out of the atmoſphere again, for then they will recede from the perpendicular; and as well in the former caſe as in the latter, the perpendicular being changed, they are inclined the ſame way, that is, towards the axis. And from this double refraction, when brought to calculation, it appears that thoſe rays of the ſun which paſs near the earth are ſo inflected as to concur in a point long before they reach to the diſtance the moon is placed at.

In ſome lunar eclipſes, the moon quite diſappears in the perfect ſhadow; in others, ſhe appears, even in the midſt of that ſhadow, of a reddiſh colour, which redneſs is ſuppoſed to ariſe from the rays of the ſun either refracted in the atmoſphere about the earth, or refracted to the moon, by the particles flying without the ſhadow of the earth, or from the illumination of the ſtars, or elſe from all theſe cauſes together.

Eclipſes recur at the expiration of a certain cycle or period, and this was firſt diſcovered by the Chaldeans, and is mentioned by Pliny in lib. 2, of his Natural Hiſtory; therefore, Dr Halley calls it the Chaldean ſaros, or the Plinian period: This period contains 223 ſynodical months, or 18 Julian years and 10 days (when the cycle or period contains 5 leap-days) and 11 days (when 4 leap days) 7 hours, 43 minutes, and 20 ſeconds; in which time, all correſpondent new moons, full moons, and eclipſes return again. This cycle is, in itſelf, very accurate, ſo that Dr Halley makes uſe of it to correct the errors of his tables; for, as he obſerves, they recur nearly of the ſame magnitude. (See his precept for correcting the computed places of the moon.) Notwithſtanding its being the exacteſt that can poſſible be invented, yet by the irregular motions of the earth and moon in their orbits, it ſometimes anticipates the true times of conjunction and oppoſition, and ſometimes follows them; but the greateſt differences which can poſſibly happen, will ſcarce amount to an hour and a quarter in a period; but it often happens, that for ſeveral periods, the difference is hardly worth mentioning.

The ſeaſons which are moſt to be ſuſpected are the two ſolſtices, i. e. if the earth be in aphelium, and the moon in perigeum, then will the time found by this rule exceed the true time; but if it happens in the winter ſolſtice, that the moon be in apogeum, then the time found by this rule will preceed, or fall ſhort of it; but it often happens, that the moon is not in theſe places at theſe times, and as often that there are no eclipſes in theſe ſeaſons. Dr Halley calculated a table of theſe minute parts of time, which were to be added to or ſubſtracted from the time found, as occaſion required: but, as the finding of them, depended entirely upon aſtronomical ſpeculations, I chuſe to omit what would puzzle, rather than improve the reader, eſpecially when it is conſidered that the moſt correct tables are liable to error; and it were much better to adviſe the young calculator, to correct his errors by a good clock or watch, (in viſible eclipſes) than to heap error upon error by tables: for, I can aſſure you, it is not every eclipſe that is ſubject to deviate thus from the truth, but only ſome one or ſo, here or there, as they occur in a period; and which, if not regarded, might, after a few periods elapſed, reform again of themſelves.

Since this rule gives us ſo near an eſtimate, without conſidering theſe momentary portions, I ſhall proceed to give an example.

Let it be required to find when the viſible eclipſe of the moon will recur, which happened on December the 2d, 9 hours, 47 minutes, in the year 1751.

Now, in order to to diſcover how many leap-days will happen in this period, obſerve the following rule: Divide the given year by 4; if nothing remains, it is leap-year; but if there be a remainder, after diviſion, that number ſhews how many years it is paſt leap-year.

The given year is 1751, being divided by 4, the remainder is 3, which ſhews that it is the third year paſt leap year; therefore the cycle muſt, of conſequence, contain 5 leap-days, becauſe the firſt year of the period will be leap year; and taking one year out of 18, the remainder 17 will contain 4 four times and one over, ſo that, upon the whole, there will be 5 leap-days in this period; therefore we muſt add 18 years, 10 days, 7 hours, 43 minutes, and 20 ſeconds to the given time to diſcover the time required, viz.

		Dec.	H.	M.	Sec.
To	1751	2	9	47	00
Add	18	10	7	43	20
	1769	12	17	30	20

Now, ſince the aſtronomical day is accounted from noon to noon, and the civil day from midnight to midnight, it follows that the 17th hour of the 12th aſtronomical day correſponds with the 5th hour of the 13th civil day, that is, the middle of this eclipſe will happen on the 13th day of December, at a little more than half an hour paſt five in the morning, in the year of our Lord 1769.

Eclipſes of the moon are always viſible, where ſhe is viſible herſelf (as was obſerved before); therefore, if the time of full moon happen in the night ſeaſon, and if an eclipſe happen at that time, it muſt of conſequence be viſible; but, an eclipſe of the Sun is very difficult to aſcertain where it will be viſible, and where not, by reaſon of the parallaxes of longitude and latitude: Therefore, the only rule I can preſcribe, is, that moſt viſible eclipſes of the ſun recur nearly at the ſame time, in the ſame place, at the expiration of three periods, viz. at the end of 54 years, and 32 or 33 days.

If, in an eclipſe, either of the luminaries be only eclipſed about one digit; at the next period, it may happen not to be eclipſed at all.

There will be elapſed 900 years in the time that the moon begins to enter the ecliptic limit, for eclipſes of the moon on one ſide, till it goes out of it on the other; in all which time there will be fifty periods and eclipſes of the moon each period: and there will be elapſed 1260 years, from the time that the moon begins to enter the ecliptic limit, for eclipſes of the ſun on one ſide of the node, till it goes out of it on the other; during which long time there will be 70 periods, and ſome where eclipſes of the ſun each period; after which long ſpaces of time, there will be no ſuch eclipſes for a much longer time.

N. B. The ſun, at the end of the period, is about $\frac{1}{2}$ *degree from the node: This ſets the moon* $2\frac{1}{2}$ *min. of a degree from the ecliptic; and as the moon's diſtance from the earth is about* 60 *ſemidiameters of the earth, every minute of a degree, at that diſtance, is equal to* 60 *geographical miles, or one degree, on the earth; conſequently* $2\frac{1}{2}$ *minutes of declination from the ecliptic, in the moon's orbit, is equal to* 150 *ſuch miles, or* $2\frac{1}{2}$ *degrees, on the earth; conſequently, when the moon is paſſing by her aſcending node, at the end of this period, her ſhadow will go* 150 *miles more ſouthward; and, when paſſing by her deſcending node, her ſhadow will go* 150 *miles more northward; and, in either caſe, in about* 500 *years, the ſhadow will have too great a latitude to touch the earth. So that any eclipſe of the ſun, which begins to touch the earth at the ſouth pole, and that muſt be when the moon is* 17 *degrees paſt her deſcending node, will advance gradually northward, in every return, for about* 900 *or* 1000 *years, more or leſs, and then go off at the north pole into the expanſum or void of the creation, and cannot take ſuch another courſe again in leſs than* 11683 *years.*

It is the ſame thing if it enters the north pole, the ſhadow will travel *at the ſame rate ſoutherly; for, the farther the moon is ſhort of either node, the farther the eclipſes go either northward or ſouthward of the ecliptic.*

I ſhall now prove that the darkneſs, which happened at the death of our Bleſſed Saviour, was ſupernatural. The Jews keep the paſſover at the time of the full moon; and, it is evident, that he ſuffered about that time, conſequently there could not be an eclipſe of the ſun, becauſe the moon would be in oppoſition, or half of the heavens diſtant from it; beſides, the time of the total darkneſs, in ſolar eclipſes, laſts not above 4 minutes in any place, whereas this darkneſs laſted 3 hours. Matthew xxviii. 15. which plainly proves it to be ſupernatural.

Having given you a rationale of the nature of eclipſes, and ſhewn you an eaſy method how to predict them; but you muſt not infer from hence, that this is the only method whereby eclipſes are predicted: No, the moſt accurate way is to calculate them from aſtronomical tables. It remains that I ſhould ſay ſomething about them.

If you divide 360 degrees (i. e. the whole ecliptic) by the quantity of the ſolar year, it will quote 59 minutes, 8 ſeconds, &c. which therefore is the quantity of the ſun's diurnal motion; and, if this 59 minutes, and 8 ſeconds, be divided by 24, you have the ſun's horary motion, which is 2 minntes, 28 ſeconds; and, if you will divide this laſt by 60, you will have his motion in a minute, &c. And this way are the tables of the ſun's mean motion, which you have in books of aſtronomical calculation conſtructed.

In like manner are tables of the moon's mean motion conſtructed, viz. by dividing 360 degrees by the quantity of a periodical month, viz. 27 deg. 7 hours, 43 minutes, 7 ſeconds, it will quote 13 degrees, 10 minutes, 35 ſeconds, which is the moon's diurnal motion, and being again divided by 24, quotes 32 minutes, 56 ſeconds, &c. for the reſt. The tables which determine the places of the luminaries are made to correſpond with obſervation. The mean diurnal motion of the node retrograde is 3 minutes, 11 ſeconds, equal to 191 ſeconds. Therefore, knowing the place of the moon's north node, any one year (as I ſuppoſe, January 1, 1758, ♌ be in 4 ſ. 5 deg. 26 min. 40 ſec. or 5 deg. 26 min. 40 ſec. in ♌; and I would have its mean place for January the 23d next following) I multiply 191 by 22, which produces 4202 ſec. which divided by 60 quotes 70 min. 2 ſec. which 70 divided again by 60, quotes 1 deg. 10 min. ſo that 1 deg. 10 min. 2 ſec. ſubſtracted from 5 deg. 26 min. 40 ſec. leaves 4 deg. 16 min. 38″ for the node's mean place in Leo, January 23, 1758, N. S.

But there are ſeveral other tables, neceſſary in accurate calculations which ought to be conſtructed according to Sir Iſaac Newton's theory of the moon, which I would recommend to every curious aſtronomer's peruſal. Books, which are furniſhed with tables of this kind, have generally precepts of their uſes inſerted in them; ſo that it would be unneceſſary to add any thing to that purpoſe.

A Table of all the Eclipſes, viſible and inviſible, of the Sun and Moon, for the Period of 18 Years, uſeful in future Calculations.

Years.	Months and Days.	D.	H.	M.	Digits.		Longitude ☽ °	′		Viſible or Inviſible	Luminaries.
1748	Jan.	29	15	25			9	43	♒	Inviſible	☉
	Feb.	13	23	49			25	16	♌	Inviſible	☽
	July	24	22	30	9	53	2	38	♌	Viſible	☉
	Aug.	8	11	34	4	38	16	32	♒	Viſible	☽
1749	Jan.	18	7	17			28	67	♑	Inviſible	☉
	June	29	21	34			8	31	♑	Inviſible	☽
	July	14	0	31			21	59	♋	Inviſible	☉
	Dec.	23	8	8	4	36	2	14	♋	Viſible	☽
1750	Jan.	7	21	12	7	9	18	6	♑	Viſible	☉
	June	19	9	9	16	9	28	16	♐	Viſible	☽
	July	3	6	51			11	28	♋	Inviſible	☉
	Nov.	28	13	19			6	46	♐	Inviſible	☉
	Dec.	12	18	32	21	6	21	13	♊	Viſible	☽
	Dec.	28	6	54			7	1	♑	Inviſible	☉
1751	May	24	2	51			3	28	♊	Inviſible	☉
	June	8	13	58	10	8	17	44	♐	Viſible	☽
	Nov.	17	12	49			25	20	♏	Inviſible	☉
	Dec.	2	9	47	8	18	10	35	♊	Viſible	☽
1752	May	13	5	45			23	14	♉	Inviſible	☉
	Nov.	5	13	59			14	2	♏	Inviſible	☉
1753	Apr.	17	6	20	5	14	27	52	♎	Ris. Ecl.	☽
	May	2	19	37			12	57	♉	Inviſible	☉
	Oct.	11	21	36			19	11	♈	Inviſible	☽
	Oct.	25	21	59	8	3	3	10	♏	Viſible	☉
1754	Mar.	23	5	52			18	14	♍	Inviſible	☉
	April	6	19	47			17	24	♎	Inviſible	☽
	April	21	22	17			2	9	♉	Inviſible	☉
	Sept.	16	1	13			23	30	♍	Inviſible	☉
	Sept.	30	22	28			7	5	♈	Inviſible	☽
	Oct.	15	13	31			22	35	♎	Inviſible	☉
1755	March	12	9	45			22	2	♓	Inviſible	☉
	March	27	12	12	7	13	7	59	♉	Viſible	☽
	Sept.	5	20	30			13	19	♍	Inviſible	☉
	Sept.	19	22	40			27	4	♓	Inviſible	☽
1756	Feb.	29	13	48			10	58	♓	Inviſible	☉
	Aug.	25	7	12			2	52	♍	Inviſible	☉
1757	Feb.	3	19	6	6	43	15	48	♌	Set ecl.	☽
	Feb.	18	1	2			0	9	♓	Inviſible	☉
	July	30	11	53	11	32	7	51	♒	Viſible	☽
	Aug.	14	10	45			22	10	♌	Inviſible	☉
1758	Jan.	9	6	11			19	33	♑	Inviſible	☉
	Jan.	23	18	13	21	27	4	20	♌	Set ecl.	☽
	Feb.	7	16	37			19	28	♒	Inviſible	☉
	July	4	20	55			13	1	♋	Inviſible	☉
	July	20	4	44			27	45	♑	Inviſible	☽

1758

Years.	Months and Days.				Digits		Longitude ☽			Viſible or Inviſible	Luminaries.
		D.	H.	M.			°	′			
1758	Dec.	29	19	29			8	40	♑	Inviſible	☉
1759	Jan.	12	19	46	6	41	22	55	♋	Set ecl.	☽
	June	24	5	23			2	46	♋	Inviſible	☉
	Dec.	19	2	14			27	29	♐	Inviſible	☉
1760	May	29	9	35	0	47	8	51	♐	Viſible	☽
	June	12	19	22	4	34	22	36	♊	Viſible	☉
	Nov.	22	9	18	6	30	1	8	♊	Viſible	☽
	Dec.	7	2	2			16	2	♐	Inviſible	☉
1761	May	4	5	40			14	33	♉	Inviſible	☉
	May	18	10	2	17	31	28	3	♏	Viſible	☽
	June	2	13	24			12	34	♊	Inviſible	☉
	Oct.	27	10	29			4	14	♏	Inviſible	☉
	Nov.	11	23	43			20	21	♉	Inviſible	☽
	Nov.	26	2	15			4	38	♐	Inviſible	☉
1762	April	23	17	28			3	58	♉	Inviſible	☉
	May	7	15	38	10	0	17	26	♏	Viſible	☽
	Oct.	16	20	12	6	10	24	0	♎	Viſible	☉
	Nov.	1	5	11	6	42	9	25	♉	Viſible	☽
1763	April	12	22	15	4	6	23	12	♈	Viſible	☉
	Oct.	6	13	5			13	28	♎	Inviſible	☉
1764	March	17	11	28	8	15	27	56	♍	Viſible	☽
	March	31	22	9	10	7	12	10	♈	Viſible	☉
	Sept.	9	19	18			18	0	♓	Inviſible	☽
	Sept.	25	5	5			3	3	♎	Inviſible	☉
1765	Feb.	19	11	45			1	40	♓	Inviſible	☉
	March	7	1	16			17	16	♍	Inviſible	☽
	March	21	1	0	2	42	11	0	♈	Viſible	☉
	Aug.	16	4	18			23	53	♑	Inviſible	☉
	Aug.	30	4	0			7	23	♓	Inviſible	☽
	Sept.	14	16	58			22	30	♍	Inviſible	☉
1766	Feb.	11	23	48			20	50	♒	Inviſible	☉
	Feb.	24	7	19			6	14	♍	Viſible	☽
	Aug.	5	6	41			13	11	♌	Viſible	☉
	Aug.	19	19	39			27	9	♌	Inviſible	☽

N. B. This table is adapted to the preſent Gregorian ſtile.

If to the moon's true longitude (at any time) there be added 10 deg. 48 min. 10 ſec. her mean motion in the ſaid period, it will give her longitude at the completion thereof, ſeldom differing ⅓ deg. from the truth.

I need not add any thing more relating to the uſe of this table, that being conſpicuous in the example of the Plinian period preceding this table. It muſt be noted, at the expiration of the Plinian period, that the eclipſes ſhift their meridians about 115 deg. 50 minutes to the weſtward: For example, ſuppoſe the middle of an eclipſe ſhould happen exactly on the meridian of London, at the end of the period its middle would fall on a meridian 115° 50′ weſt of that meridian.

A Table of all the viſible Eclipſes of the Sun and Moon to the Year 1800.

		Days	H.		
1758,	Jan.	24	6	M	M ●
1759,	Jan.	13	7	M	M
1760,	May	29	10	A	M
	June	13	7	M	S
	Nov,	22	9	A	M
1761,	May	18	10	A	M ●
1762,	May	8	4	M	M
	Oct.	17	8	M	S
	Nov.	1	9	A	M
1763,	April	13	10	M	S
1764,	March	17	11	A	M
	April	1	10	M	S
1765,	March	21	2	A	S
1766,	Feb.	24	7	A	M
	Aug.	5	7	A	S
1768	Jan.	4	6	M	M
	June	30	3	M	M ●
1769,	June	4	7	M	S
	Dec.	13	6	M	M
1770,	Nov.	17	16	M	S
1771.	April	28	2	M	M
1772,	Oct.	11	6	A	M
	Oct.	26	9	M	S
1773,	Sept.	30	7	A	M
1774,	March	12	9	M	S
1775,	Aug.	26	5	M	S
1776,	July	30	12	A	M ●
	Dec.	4	6	M	M
1777,	Jan.	9	2	A	S
1778,	June	24	4	A	S
1779,	June	14	7	M	S
	Nov.	23	7	A	M
1780,	Nov.	12	4	M	M
1781,	April	23	6	M	S
	Oct.	17	8	M	S
1782,	April	12	6	A	S
1783,	March	18	8	A	M ●
	Sept.	10	11	A	M ●
1784,	March	7	3	M	M
1785,	Feb.	9	1	A	S
1787,	Jan.	3	12	A	M ●
	Jan.	19	10	M	S
	June	15	5	A	S
1788,	June	4	7	M	S
1789,	Nov.	2	12	A	M
1790,	April	14	10	M	S
	April	28	12	A	M ●
	Oct.	22	2	M	M ●
1791,	April	3	2	A	S
	Oct.	12	4	M	M
1792,	Sept.	16	5	A	S
1793,	Feb.	25	10	A	M
	Sept.	5	2	A	S
1794,	Jan.	31	10	M	S
	Feb.	14	10	A	M ●
1795,	Feb.	4	1	M	M
	July	31	8	A	M
1797,	June	24	5	A	S
	Nov.	18	4	A	S
	Dec.	4	4	M	M
1798,	Nov.	23	7	M	M ●
1800,	Oct.	1	11.	A	M

N. B. The firſt of the two letters, placed after the days and hours, ſhews whether the eclipſe be in the morning or afternoon; and the ſecond, whether it be of the ſun or moon. Thoſe marked thus ● are total eclipſes.

CHAP. III.

Of the Utility of Eclipſes.

BY eclipſes, we diſcover that the ſun is bigger than the earth, and that the earth is larger than the moon; for if an illuminated body be larger than an object, the ſhadow which that object caſts, will converge and terminate in a point. But if an object be larger than the illuminated body, the ſhadow which that object has diverges, and the farther it flies the larger it is; this is demonſtrable by holding your hand, or any thing which is broader than the flame of a candle before it, and obſerving its ſhadow on the oppoſite wall, which will appear larger the farther it is diſtant from it. But, if the object be leſs than the flame of the candle, the farther the ſhadow goes the leſs it is, till at laſt it ends in a point. Now, we prove that the ſun is larger than the earth, becauſe, when the earth came between the Sun and Mars, the cone of its atmoſphere and ſhadow could not reach that planet to occaſion any eclipſe, as it does when it darts againſt the diſk of the moon. That the earth is larger than the moon, is evident from the cones of their ſhadows; for the cone of the earth's ſhadow involves the moon's diſk a conſiderable time in total eclipſes of the moon, whereas in ſolar eclipſes, in one part of the earth it is total, in another part partial, and in another part there is no eclipſe at all, which plainly proves that the earth's ſhadow takes more compaſs than the moon's.

Hence it follows, that ſolar eclipſes can be of no ſervice in determining the longitudes of places, becauſe they are not viſible in all places where the ſun enlightens, which is not the caſe with the moon; for if ſhe ſuffers an eclipſe, it is viſible in all parts of the world where ſhe is viſible herſelf.

If a ſhip were at ſea, and the mariners ſhould obſerve the middle of an eclipſe, Jan. 24, 1758, at five in the morning, look in the table, and you will find the middle of the eclipſe, at London, will happen Jan. 23, 18 hours, 13 minutes, which correſponds to January the 24th, 13 minutes paſt ſix o'clock; the difference of meridians being 1 hour, 13 minutes, which in degrees is 18° 15′; ſo that the ſhip is then ſo much weſt of the meridian of London.

It is an eaſy matter to find the latitude at any time, by taking the ſun or ſtars meridian altitude, and having its declination given at that time, its zenith diſtance being the complement to a quadrant, or 90 degrees, of its meridian altitude; then if its zenith diſtance and declination be both of one name, either both north or both ſouth, their difference is the latitude of the place of the ſame name with the declination, if it was the greater number, and of a contrary name of it was the leſs; but if the zenith diſtance and declination be of contrary names, i. e. one north and the other ſouth, add them together, the ſum is the latitude of the ſame name with the declination.

If the object be in your zenith, the declination is the latitude of the ſame name with the declination; and if the object have no declination, but is upon the equator, the zenith diſtance is the latitude of a contrary name to the zenith diſtance.

Laſtly, if the object be obſerved upon the meridian below the pole, then add the zenith diſtance and declination together, and ſubſtract the ſum from 180 degrees, the remainder is the latitude of the ſame name, with the declination.

Note, the zenith is that point which is directly over our heads; and the zenith diſtance is the diſtance between that point and the place of the ſun or ſtar.

By theſe rules it is eaſy to find the latitude of any propoſed place, by having only tables of the object's declination by one, i. e. Such tables as ſhew how far the object is north or ſouth of the equinoctial line, ſince latitude, either north or ſouth, is counted from this line: But as all celeſtial objects appear to move from eaſt to weſt ſucceſſively, there can be no determinate point, or line to account longitude from in the heavens; ſo that different nations reckon from different meridians, and we in England account from the meridian of London; and ſuch places as lie eaſt of London, we ſay, have eaſt longitude; and ſuch as lie weſt of that metropolis have weſt longitude.

Several ways have been thought of to find the longitude at ſea, the great deſideratum of the art of navigation; for doing of which, ample rewards have been promiſed by ſeveral nations; as by the eclipſe of the moon, her tranſit over or appulſe to any eminent fixed ſtar, the eclipſes of Jupiter's ſatellites, &c. which are all true in theory, and may be practiſed aſhore with the greateſt exactneſs. For the time of any one of theſe phœnomena being truly calculated for the meridian of London (ſuppoſe, or any other) and tables may be eaſily made of all of them, which the navigator may carry to ſea with him. If then he could but obſerve the time of the eclipſe or tranſit at ſea, with accurate exactneſs, the difference of time of the eclipſe happening to him, ſooner or later than at London, would give the exact longitude of the place of the ſhip, either eaſt or weſt from the meridian of London; (for, every 15 degrees of the equator anſwer to an hour in time, one degree of it being 4 minutes in time, and one minute of a degree there being 4 ſeconds of time, and 15 minutes one minute of time): But the misfortune is, ſuch an obſervation of an eclipſe, and the exact time of the immerſion or emerſion of the deficient body into or out of the ſhadow, is not to be made without teleſcopes of ſuch a length, as the motion of the ſhip will not permit to be uſed at ſea; though, by the by, if ſhips were ſent with good inſtruments, and men that know how to uſe them, to do this, at all the capes and headlands of the world, it would be a thing of the greateſt uſe; and, by ſettling the longitude of all theſe places, would reduce many long voyages into ſhort ones, and afford means of continually rectifying the dead reckoning at ſea. But to return, others being fully ſatisfied of the impracticableneſs of the method of eclipſes, for finding the longitude at ſea, have thought of doing it by a clock or watch; which indeed, if it could be made to go right all the time of a long voyage, would give the longitude at any time, when the true hour of the day or night could be had under any meridian, or in any place of the earth: For, the clock going true for the meridian, it was firſt ſet at, will ſhew the true hour of the day or night under any meridian, or in any place of the earth; and then the true hour being found by the ſun or ſtars, in the place where the ſhip is, the difference between that and the clock's hour will be the difference of the meridian in time, or longitude in degrees. But it is not eaſy to make ſuch a movement, as will keep going in all weathers and all climates truly, eſpecially in ſome of the ſouthern ones, where the dews are ſo great as to ruſt the parts of it, and ſo retard if not ſtop its motion.

another inconveniency is, that, in different latitudes, the hours, ſhewn by the clock, will be different from thoſe ſhewn by it, for the latitude to which it is fitted; as a clock at London, made to ſhew the time there, when carried under the equinoctial, will go too ſlow by two or three minutes, and the law of retardation, as you go ſouthwards, is not yet well known. Notwithſtanding this, Mr Huygens, in his excellent *Horologium oſcillatorium*, mentions two clocks, that were formerly made by his directions there laid down, being carried to ſea in an Engliſh ſhip, in company with three other ſhips, which very much aſſiſted the captain to judge of the true place of the ſhip: For, the captain ſaid, when they had ſailed from the coaſt of Guiney to the iſland of St Thomas, under the equinoctial circle, and there ſet the clocks to the ſun, they ſailed weſtwardly about 70 miles, and then directed their courſe towards the African ſhore; and, when they had continued on, upon a courſe, for about 2 or 300 miles, the captains of the reſt of the ſhips, fearing they ſhould want water before they could arrive at the coaſt of Africa, would have them to go to get water at the American iſlands, called the Caribbees; and, a conſultation being held thereupon, the journals and reckonings of each ſhip were produced, all which differed from the captain's, who had the clocks aboard; one, 120 miles; another, 100; and the third, ſtill more. But the captain himſelf ſaid, he gathered from his clocks, that they were not more than 30 miles from one of the African iſlands, called del Fuego, nigh to the coaſt of Africa, and might arrive at the ſame the next day. And, ordering them to direct their courſe, accordingly they ſaw the ſaid iſland the next day at noon, and in a few hours after arrived at the ſame.

Mr Huygens, in the ſame book, ſays, that afterwards, by the command of Lewis XIV. the French and Dutch, made various experiments with his clocks, but with various events, which he attributed often more to the negligence and unſkilfulneſs of the perſons, to whoſe care they were committed, than to the faults of the clocks themſelves. See more, page 17, *Horol. oſcillat.* But the moſt ingenious and beſt clock that ever was, or perhaps ever will be, made for this purpoſe, is that of Mr Harriſon, of Leather-Lane, London, according to accounts given by perſons who are reckoned good judges.

By eclipſes alſo, we diſcover the true figure of the earth to be ſpherical or nearly ſo; for, in lunar eclipſes, the ſhadow of the earth falling on the moon's diſk always appears circular, whether it falls to the eaſt, weſt, or ſouth; and its diameter, greater or leſs, according as the moon is more or leſs diſtant from the earth: It is evident, from optics, that the figure of the earth is, in appearance, at leaſt ſpherical. Alſo, by eclipſes of the ſun, which are cauſed by the interpoſition of the moon between the ſun in thoſe places where it appears eclipſed; I ſay, it could not be determined when, and in what places, ſuch eclipſes ſhould appear, if the earth's figure were unknown. As I have entered into this ſubject, I ſhall advance ſome other teſtimonies, which will plainly prove the figure of the earth to be ſpherical: 1ſt, The ſpherical figure of the earth is evinced alſo from the riſing and ſetting of the ſun, moon, and ſtars, which happen ſooner to thoſe who live to the eaſt, and later to thoſe living weſtwardly, and that more or leſs, according to the roundneſs of the earth: 2d, In going or ſailing to the northward, the north pole and northern ſtars become more elevated, and the ſouth pole and ſouthern ſtars more depreſſed; the elevation, northerly, increaſing equally with the depreſſion ſoutherly, and, either of them, proportionably to the diſtances gone.

The ſame thing happens in going to the ſouthward. Now, in going ever ſo far on a plain, the ſaid ſtars would ever appear of the ſame height above the horizon. 3d, The oblique aſcenſions, deſcenſions, emerſions, and amplitudes of the riſing and ſetting of the ſun and ſtars in every latitude, are agreeable to the ſuppoſition of the earth's being ſpherical; all which could not be ſo, if the earth were of any other figure. 4th, If one ſtands upon the ſea ſhore, and ſees a ſhip afar off under ſail, making towards the land; at firſt we ſee only the topſails or higheſt parts, and at the ſame time do manifeſtly behold the convex ſurface of the ſea interpoſed between our ſight and the hull or lower parts of the ſhip, till ſhe approaches nearer, and this uniformly every way alike, and proportionably to the ſeveral diſtances, which is an evident proof of the roundneſs of the ſea; for, if the ſurface of the ſea were a plain, ſuch appearances could never happen. 5thly and laſtly, the roundneſs of the earth moſt manifeſtly appears from the voyages of ſeveral Europeans, who have ſailed quite about the ſame, conſtantly continning their courſe weſterly, returned again to Europe eaſterly, obſerving all the way every phænomenon conſequent from the roundneſs of the earth. Although the ſurface of the earth and ſea is ſaid to make but one continued round, yet this, in reality, is not to be ſo ſtrictly taken, as to have no inequality in it: but, as a ball, though it has ſome duſt or ſmall grains of ſand upon it, may ſtill be ſaid to be round; ſo, though the land, hills, and mountains be ſomewhat raiſed above the ſpherical ſurface of the ſea, and ſome vallies depreſſed below it, yet becauſe the greateſt of theſe inequalities has ſcarcely any ſenſible ratio to the whole, it may well be affirmed to be round. It is not many years ſince the true figure of the earth has been diſcovered; for, ever before, it was taken, by mathematicians and geographers, as perfectly ſpherical, excepting the ſmall inequalities in its ſurface, of mountains, valleys, &c. But now it is evident, that the figure of the earth is an oblate ſpheroid, formed by the rotation of an ellipſis about its leſſer axis, ſo that thoſe diameters are longeſt of all, belonging to the circle between the middle of the poles, or the equator, and thoſe more remote from it are ſhorter, till you come to the axis, joining the poles of the earth, which is the ſhorteſt of all. What gave firſt occaſion to the knowledge of this, was the obſervations of ſeveral Frenchmen in the Eaſt-Indies, about 100 years ago, who found that pendulums, the nearer they came to the equator, performed their viberations ſlower; from whence it follows, that the velocity of the deſcent of bodies, or gravity, is leſs in the countries near the equator than thoſe near the poles. And this ſet Sir Iſaac Newton and Mr Huygens to work, to find out the cauſe, which, they ſay, is the revolution of the earth about its axis; for, ſince it moves much ſwifter, at the equator, than at the poles, the diminution of the weight of bodies there muſt be found greater than near the poles; and ſo thoſe parts of the ſea, ſituate near the equator, being by this cauſe made lighter, are thrown up to a greater height. Mr Huygens makes the ratio of the polar diameter, to that of the equator, as 577 to 875; and, Sir Iſaac Newton, as 689 to 692. Since the earth is of an oblate ſpheroidal figure, ſwelling out towards the equator, and flatted or contracted towards the poles, ſo the diameter of it, at the equator, is longer than the axis by about 34 miles: Upon this account there ariſes a ſmall inequality in the magnitude of a degree of latitude; for, they increaſe from the equator to the poles by nearly the 800th part: But this difference of increaſe is ſo very ſmall, that in meaſuring degrees, by inſtruments, it cannot be diſcovered. Hence it alſo follows, that heavy bodies do not tend directly to the earth's center, unleſs at the poles and equator, but every where perpendicularly to the ſurface of the ſpheroid. Having, I hope, ſufficiently proved from the aforeſaid teſtimonies concurring, that the figure of the earth is ſpherical, or rather ſpheroidal; notwithſtanding, ſeveral of our learned fathers, as Lactantius, St Auguſtine, and ſome others, have ſuppoſed it to be a vaſtly extended plain, having a bottomleſs foundation; and this fictitious hypotheſis has been as gravely defended by ſome of the fathers of the Chriſtian church, as if it had been a ſubject of revelation. Nay, not many ages ſince, the doctrine of the Antipodes was zealouſly oppugned as a damnable hereſy; and, hiſtory informs us, that the learned Spigelius, biſhop of Upſal, ſuffered martyrdom, at the ſtake, in its defence. Yet, from this, we muſt not attribute theſe diſcoveries entirely to the moderns; for Thales, the Grecian, was ſufficiently acquainted with the figure of the earth, or elſe he could not have predicted an eclipſe of the ſun, which he did upwards of 570 years before the birth of our Saviour Chriſt; where, it muſt be noted, he is ſaid to be the firſt that ever calculated an eclipſe: And Anaximander, his ſcholar, was the firſt who gave an account of the circumference of the ſea and land 550 years before the birth of Chriſt, which plainly evinces they both knew the figure of the earth to be ſpherical. As to it meaſure, our countryman, Mr Richard Norwood, who, in the year 1635, meaſuring the diſtance from London to York with a chain, and taking the ſun's meridian altitude the 11th of June, with a ſextant of above five feet radius, found a degree to contain 367200 feet or 69 miles and a half, and 14 poles; and thence, the circumference of a great circle of the earth, is a little above 25036 miles, and the diameter than 7966 miles; and this meaſure is allowed by every one to be as exact as any whatever. See the particulars of the whole affair in his Seaman's Pactice.

For Mr Caſſini the younger, in the year 1700, by the French king's command too, went about this buſineſs with a quadrant of 10 French* feet radius, for taking the latitude, and another of $3\frac{1}{8}$ feet, for taking the angles of the triangle; and found a degree, from his calculation, to contain $28\frac{323}{500}$ toiſes, or $69\frac{783}{1760}$ Engliſh miles; and, this meaſurement, being performed with all the care and exactneſs poſſible, muſt be looked upon as very near the truth, and differs from our Norwood's only 8 toiſes. See *l'Hiſt. de de l'Acad. Roy. An.* 1702.

N. B. The eaſieſt and propereſt method of finding the circumference of a great circle of the earth is, by meaſuring along, under the ſame meridian line, either north or ſouth till the north pole ſtar become one degree elevated or depreſſed, *i. e.* if you meaſure northwards, the pole muſt be one degree elevated; but, if you meaſure ſouthwards it muſt become one degree depreſſed.

Eclipſes may alſo prove ſerviceable to chronologers in determining the preciſe time of any remarkable occurrence; for, if they ſhould compute the ſpace between an eclipe and the occurrence, which might happen either before or after the eclipſe, (as ſome of the ancients did) it would greatly confirm their annals, eſpecially if they did but remark what ſigns, degrees, &c. the luminaries were in, when the eclipſes happen'd.

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* A French foot exceeds an Engliſh foot of 12 inches by $\frac{8}{10}$ or eight-tenths of an inch.

I ſhall conclude this diſcourſe with ſome remarks on the fictitious notions which the ancients entertained of the moon, when ſhe was eclipſed. Their ſuperſtition taught them to look on the moon as the goddeſs who preſided over the earth, and their credulity (for the ignorant believe any thing) made them fit tools for magicians and inchanters to work upon; for theſe deceitful wretches made them believe, that it was in their power to bring the goddeſs down from her ſphere, and to torture her by muttering over ſome charms and incantations in verſe; and, when an eclipſe happened, they really believ'd ſhe was actually ſick, and laboured as in an agony, and ſuffered a kind of death, and endeavoured to relieve her, by ringing of bells, ſounding of trumpets, beating of braſs veſſels, and making great noiſes, by hallowing, hooting, &c. to drown the muttering of witches, that the moon might not hear them, and ſo receive no harm. Yea, ſo great was the ſtupidity and ignorance of the ancients, that even Steſichorus and Pindar, two poets of great name, were of this ridiculous opinion, if we believe Pliny the hiſtorian. And this ſtrange and abſurd piece of ſuperſtition is practiſed to this day among the Turks and Heathen nations, with many and various ridiculous ceremonies more than I have related, as hiſtorians inform us. Plutarch relates, in his life of Nicias, that when the ſoldiers were commanded to embark upon an expedition, there happened that night an eclipſe of the moon, which very much ſurprized their general and all the ſoldiers; and by reaſon of their ignorance of the cauſe thereof, it poſſeſſed them with great apprehenſions of ill luck; for, ſays he, many knew the cauſe of eclipſes of the ſun, but they had not leaſt ſuſpicion what ſhould make the moon, when ſhining with a full face, to inſtantly loſe her light and colour, and interpreted this to be no other than a token ſent by God, of ſome impending calamity that would happen them.

About the year 1493, Chriſtopher Columbus, while he lay off Hiſpaniola, there aroſe ſome difference between him and ſome of the Indians; and the mutineers ſo far prevailed, that the natives ſlacked their hands in ſupplying him with proviſions, which reduced him to great diſtreſs; but he extricated himſelf by this lucky ſtratagem. He knew there would be a lunar eclipſe in three days time, at the riſing of the moon, at the beginning of the night, and ſent an Indian interpreter for the chief of the Indians of the place, to diſcourſe them about a matter of importance. When they came, he told them, by the interpreter, that the Chriſtian's GOD, who lived in heaven, took care of the good and puniſhed the bad, and that the ſame God would puniſh the Indians for not bringing proviſions to him and his men; and, as a ſure preſage of it, they ſhould ſee the moon riſe, ſuch a night, with an angry and bloody aſpect. Some of the natives were affrighted at this relation, and others mocked him; but when they ſaw the eclipſe, as he had foretold, they believed what he ſaid, came and prayed him to intercede with his God on their behalf, and promiſed to ſupply him with what proviſions he needed.

The admiral replied, that he would; and, as a proof of it, they ſhould ſoon ſee the moon put off her angry countenance by degrees: The eclipſe being over, they concluded the admiral could not have known this, except it had been revealed to him from heaven.

CHAP.

CHAP. IV.

A Synopſis of Comets, containing an Account of their Subſtance; how they move in the Heavens; how to calculate them; of the Danger of their Approach too near the Earth; with an Account of what Benefit the World may receive from them, &c.

A Comet is an opake, ſpherical, and ſolid body like a planet, performing revolutions round the ſun in elliptical orbits, which have the ſun in one of the foci. The antients were divided in their opinions concerning them, ſome conſidering them as wandering ſtars, others as meteors kindled in the atmoſphere of the earth, ſubſiſting for a time and then diſſipated; others looked upon them as prodigies: But it is put beyond doubt by the accurate obſervations of the late aſtronomers, that they are a kind of planets. That they are not meteors is obvious, for if they were they could not bear that vaſt heat which ſome of them in their perihelion receive from the ſun.

The great comet which appeared in the year 1680, Sir Iſaac Newton ſays went ſo near the ſun, that it was heated 2000 times as much as a red hot iron; and conſequently, if the comet had been a meteor or an aggregate of vapours, the ſun would have rendered it inviſible.

That comets are not only above the air, but alſo beyond the moon, is plain; becauſe comets ſeen from diſtant places are obſerved to be at the ſame diſtance from a fixt ſtar which is near them. As for example, the comet which Tycho Brache obſerved at Uraniburg, was likewiſe ſeen by Hagecius at Prague in Bohemia at the ſame time, which two places differ ſix degrees in latitude, and are nearly under the ſame meridian, and both meaſured the diſtance of this comet from the ſtar we call the Vulture, that is, how much it was below towards the horizon, for both the Vulture and the comet were in the ſame vertical circle, and both obſervators found their diſtances the ſame; and conſequently they both viewed the comet in the ſame point in the heaven, which could not be unleſs it had been higher than the moon.

The famous Sir Iſaac Newton, in his excellent Principia philoſ. math. has a large diſcourſe of comets, p. 473, &c. where he proves, that they are above the moon, and in the regions of the planets, becauſe they have no diurnal parallax, but an annual one. For thoſe comets which move forward according to the order of the ſigns, are all at their exit, or diſappearance, ſlower in their motion than they were before, or retrograde if the earth be between them and the ſun; but they move ſwifter than ordinary when they begin to diſappear, if the earth be in oppoſition to the ſun: And on the contrary, if they move contrary to the ſucceſſion of the ſigns, and have the earth between them and the ſun, then they move ſwifter than ordinarily at their exit; but if the earth be in oppoſition, they move ſlower, and retrograde towards their going off. This chiefly depends on the motion of the earth, as it is in the planets, which according as the earth's motion agrees with, or is contrary to theirs, appers ſometimes retrograde, ſometimes to move ſlower, and other times more ſwiftly.

If the earth move the ſame way with the comet, and ſwifter by its angular motion round the ſun, then the comet when beheld from the earth will appear to be retrograde. And if the earth move ſlower than it, the motion of the comet (ſubducting the motion of the earth) will be to appearance ſlower. But if the earth move contrary way to the comet, it will appear to move ſwifter than the earth: All which he illuſtrates and proves; and ſhews alſo a way from the comet's parallax to find its diſtance.

From the conſideration alſo of the curvity of the way of a comet, he concludes, that when they diſappear, they are much below the orb of Jupiter: And in their perigeums and periheliums, they often deſcend below the orbits of Mars and the inferior planets.

From the light alſo of the apparent ſtar that is in the head of the comet, he concludes their vicinity to the ſun and earth, and that they can by no means be in the region of the fixed ſtars, as ſome have imagined, for then their heads could no more be enlightned by the ſun, than the planets are by the fixed ſtars.

Conſidering alſo the obſcuration of the comet by that thick fume or vapour with which its head is always encompaſſed, he concludes, that they muſt often deſcend down below the ſphere of Saturn, as he had before found by their parallax.

The ſame thing he concludes alſo by examining into the cauſe of the coma or tail, and then draws theſe corollaries.

1. That comets ſhine by the light of the ſun's beams reflected from them.

2. That the heavens are devoid of all reſiſtance, ſuch as our air and other mediums have; For thoſe comets move every way with all the freedom that can be, obliquely, directly, and often againſt the courſes of the planets, and yet continue their motion for a very long while even ſo.

And therefore the celeſtial regions cannot be filled with matter like the Carteſian vortices, but muſt be almoſt void ſpaces.

There are three ſorts of comets, 1. Cometa crinitus, having a tail like that of an horſe. 2. Cometa barbatus, having a tail like a beard. 3. Cometa enſiformis, having a tail like a ſword.

Their magnitude has alſo been obſerved to be very different, many of them without hair appear no bigger than ſtars of the firſt magnitude. But ſome authors have given us an account of others which were greater, ſuch as that which appeared in the time of the emperor Nero, which Seneca relates was not inferior in magnitude to the ſun itſelf. In like manner the comet which Hevelius obſerved in the year 1652 did not appear much leſs than the moon, tho' it had not ſo bright a ſplendor, for it had a pale and dim light, and appeared with a diſmal aſpect.

Moſt have a denſe and dark atmoſphere ſurrounding their bodies, which weakens and blunts the ſun's rays; but within it, appears the nucleus or ſolid body of the comet, which, when the clouds are diſperſed, gives a ſplendid and briſk light.

The particulars in which comets differ from planets are, that they move in various directions, ſome the way with the planets, others the contrary; neither are their motions confined within the zodiac, their orbits admitting of any inclination to the ecliptic whatever. And the eccentricity of their orbits is ſo very great, that ſome of the comets perform the greateſt part of their motion almoſt in right lines, tending in their approach to the ſun almoſt directly towards it, after which they paſs it; and when they leave it, go off again nearly in a right line, till they are out of ſight, as if they were haſtening back to the fix'd ſtars. As they approach the ſun, their motion grows proportionably ſwifter; for they deſcribe equal areas in equal times about its center, as the planets do. Hence it is, that when they are in their perihelia, their motion is immenſely ſwifter than when they are in their aphelia.

This will better appear from the following inſtance: If we ſhould ſuppoſe the ſemiaxis of the comet's orbit to be 100 times greater than the ſemiaxis of the earth's orbit, or, which is the ſame, than its mean diſtance from the ſun, that comet would not compleat its revolution in leſs than 1000 years; for the ſquares of the periodical times of the earth and comet, muſt be as the cubes of their mean diſtances from the ſun; and the comet becomes viſible only for that part of its period wherein it deſcends towards the ſun, and approaches near the earth; and then after it has paſt its perihelion, conſtantly riſing higher from the ſun, it will ſoon begin to vaniſh, and will not be viſible without a teleſcope. If the aphelion diſtance be to the perihelion, as 1000 is to 1, the velocity or ſwiftneſs of a comet in the perihelion will bear the ſame proportion to the velocity of the aphelion, for it muſt deſcribe equal areas in equal times, and whoſe orbit being ſo very eccentrical an ellipſis, it is evident that the arch it deſcribes when in its perihelion muſt be greater than the arch it deſcribes in the aphelion, in the ſame proportion as its aphelion diſtance is greater than its perihelion diſtance, or as 1000 to 1. This is the proportion of their abſolute velocities. But their angular velocities about the ſun are in a duplicate proportion of theſe diſtances, or as 1000000 to 1; ſo that while the comet in its perihelion deſcribes one degree with its angular motion, when it aſcends to its aphelion it will deſcribe in an equal time but $\frac{1}{1000000}$ of a degree. Hence then is ſeen the cauſe why comets are viſible to us for ſo ſhort a time; and when they diſappear, why they are ſo long before they viſit us again. This alſo deſtroys the objection againſt the return of comets drawn from the rarity of their appearance. As the elliptic orbit of a comet is ſo very eccentric, that portion of it wherein it becomes viſible to us may paſs for a parabola, by conſidering therefore, that portion as a piece of a parabola near its vertex; the calculation of their motions becomes much eaſier, and upon that hypotheſis Dr Halley has conſtructed and calculated a table, by which, whenever a new comet ſhall appear, it may be determined whether it be any of thoſe which have yet appeared, and conſequently its period, and the axis of its orbit be determined, and its return foretold.

From this table, as well as from obſervations of aſtronomers, it ſeems probable that the comet which appeared in the year 1682 was the ſame which was ſeen before in 1607 and 1531, and therefore may be expected again in the year 1758, after a period of about 75 years and a half. And that the great comet which appeared in the year 1680, was the ſame ſeen in the time of K. Henry I. in 1106, and in 531, and in the 44th year before Chriſt. And Mr Whiſton, in his theory of the earth, makes it very probable that the ſame comet was in our ſyſtem at the time of Noah's flood. The period of this comet is about 575 years.

For the ſatisfaction of the curious, I have collected the following table from Dr Halley's aſtronomy of comets.

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The TABLE.

The times when they were neareſt the ſun,				*The leaſt diſtance from the ſun.*	*The periods.*	*When they will appear again.*	
Years.	d.	h.	m.		Years.	Years.	
1607 Oct.	16	3	50	58680	$75\frac{1}{2}$	1758	Retrogr.
1661 Jan.	16	23	41	44851	129	1789	Direct.
1672 Feb.	20	8	37	69739	140	1812	Direct.
1680 Dec.	8	0	6	$612\frac{1}{2}$	575	2255	Direct.
1682 Sept.	4	7	39	58328	$75\frac{1}{2}$	1758	Retrogr.

N.B. The comet which appeared in 1743 and 1743-4, its periodic time is found by calculation to be 310, and therefore may be expected again in 2014.

The above table needs little explication, ſince it is plain enough from the titles what the numbers mean: Only it may be obſerved, that the perihelium diſtances are eſtimated in ſuch parts, as the middle diſtance of the earth from the ſun contains 100000.

Note, To avoid miſtake, the reader is to obſerve, that the days of the months are accounted according to the Julian ſtile.

Altho' the comet which is expected in the year 1758, was ſo nicely calculated by ſome of our aſtronomers to approach the earth's orbit the ſame year on the 12th day of May (ſo near as to envelope the earth in its tail) has refuted them, yet we are not to infer from this, that it has deceived them all; for our learned aſtronomer Dr Halley, who was the firſt that attempted to foretell the appearance of any comet, knew better the nature of their motions than to pretend to ſuch preciſeneſs. He tells us in the firſt place, that two periods of this comet are finiſhed in 151 years nearly, and that each alternately, the greater and the leſs are compleated in about 76 and 75 years, and therefore he concluded its period at a mean to be in $75\frac{1}{2}$ years. He intimates alſo that the difference of the periodical revolutions of this comet is occaſioned by its gravitating towards the centers of the planets as it paſſes by their orbits, which muſt be different at different times, becauſe it cannot be ſuppoſed that the planets are always in the ſame parts of their orbits when the comets go paſt them, and therefore the effect muſt be greater or leſs, according as they are near or remote from that part which it goes paſt. The truth of which he proves from the periods of the planet Saturn, which are longer at ſometimes than others by 13 days, which is occaſioned by the force of gravity tending towards the center of Jupiter.

Our author alſo informs us, that it is probable that its return will not be until after the period of 76 years or more, about the end of the year 1758, or the beginning of the next.

Now if it ſhould appear any time in the year 1759, we may conclude the doctor has accurately enough foretold its return, when we conſider how liable it is to be affected by the ſecret power of attraction, which may deceive the moſt ſagacious calculator.

This comet, ſays our author, is as it were the Mercury of the comets, ſurrounding the ſun with a leſſer orbit, and ſhorter periodic time, whilſt all the reſt expatiate more widely, and after very long and more than ſecular revolutions, nay of many ages duration, offer themſelves to the ſight of men for but a little ſpace of time, to wit, only while being in the neighbourhood of the ſun.

It will appear in our northern hemiſphere under the following conſtellations, viz. the Great Bear, or Charles's Wain, Arcturus and Bootes, the Serpent, Hercules, and ſeveral other circumpolar ſtars*. But it muſt be remarked, that the inclination of its orbit in the year 1682 exceeded that of the year 1607, by 22 intire minutes, which our author ſuppoſes was was occaſioned by its conjunction with the planet Jupiter in its deſcent towards the ſun.

Few comets are ſeen in their acceſs to the ſun, but in their receſs appear with long fiery tails, pointing directly, or nearly ſo, towards that part of the heavens which, with reſpect to the comet, is oppoſite to the ſun, and begin to put forth their tails, which at firſt are ſhort and thin, ſeldom exceeding 15 or 20 degrees in length, but grow longer and denſer as the comet comes nearer the ſun. If the comet paſſes very near the ſun, it then ſends forth fiery beams of light every way. After this it puts forth a tail forty, fifty, or ſixty degrees long, which, as the comet recedes farther from the ſun, continually diminiſhes both in length and ſplendor; but is larger and longer at any diſtance in its receſs from the ſun than at an equal diſtance in its acceſs to it.

In order to account for the formation of the tails of comets, ſome have ſuppoſed that the heads of comets are tranſparent, and that their tails are no other than a beam of the ſun tranſmitted through them. But were the heads of comets tranſparent, they themſelves would be ſcarcely viſible; others that they ariſe from the refraction of the rays of light in their way from the comet to us: But if ſo, then both the planets and fixed ſtars ought to have tails alſo.

The learned John Kepler of Wittemberg in Germany, aſcribed the aſcent of the tails to the rays of the ſun carrying the particles of the comet's atmoſphere with them, that is, impelling them into the regions oppoſite to it. But we have no inſtance of any thing in nature like this: It is therefore an hypotheſis that cannot be ſupported. Sir Iſaac Newton thinks the great ſplendor and length of the tails ariſes from the heat which the ſun communicates to the comet as it paſſes near it. As the aſcent of the ſmoke in a chimney is owing to the impulſe of the air with which it is intangled, in like manner, ſays he, the tail of a comet may riſe from the atmoſphere thereof into thoſe parts which are oppoſite to the ſun, being carried up by the æther about the comet, rarefied to a very great degree by the heat thereof. This opinion is greatly corroborated by the appearance of the tails, for when accurately obſerved, they are found not to riſe always in a direction preciſely oppoſite to the ſun, but to deviate or incline a little from thence towards thoſe parts which the comet has lately left; and not only ſo, but to be bent into a certain curvature, the extremities of the tails deviating from the true oppoſition more in proportion than the other parts; and to be more denſe, ſeemingly, and better defined on the convex than on the concave ſide. And further, that the longer the tail is, the more ſenſible is the curvature, as being the greateſt at the greateſt diſtance from the body of the comet.

Upon theſe accounts, Sir Iſaac Newton thinks it is evident, that the phænomena of the tails of comets depend on the motion of their heads, and that the heads furniſh the matter which forms the tails. Mr Rowning,

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* Circumpolar ſtars are thoſe which never ſet or go below our horizon, but are on different points of the compaſs on different hours in the night.

ing, who is not ſatisfied with Sir Iſaac's opinion, accounts for the tails of comets in the following manner: It is well known, ſays he, that when the light of the ſun paſſes through the atmoſphere of any body, as the earth, that which paſſes on one ſide is by the refraction thereof made to converge towards that which paſſes on the oppoſite one; and this convergency is not wholly effected either at the entrance of the light of the atmoſphere, or at its going out; but that beginning at its entrance, it increaſes in every point of its progreſs, It is alſo agreed, that the atmoſphere of the comets are very large and denſe. He therefore ſuppoſes, that by ſuch time as the light of the ſun has paſſed through a conſiderable part of the atmoſphere of a comet, the rays thereof are ſo far refracted towards each other, that they now begin ſenſibly to illuminate it, or rather the vapours floating therein, and ſo render that part which they have yet to paſs through viſible to us; and that this portion of the atmoſphere of a comet thus illuminated, appears to us in the form of a beam of the ſun's light, and paſſes under the denomination of a comet's tail.

This hypotheſis of Mr Rowning, how well it anſwers to the phænomenon of tails, may be ſeen in his ſyſtem of natural philoſophy, Part IV. Chap. 11.

To determine the apparent place and courſe of a comet. One method by which aſtronomers inveſtigate them is this: They obſerve what two ſtars are directly one on one ſide of the comet and the other on the other; which is done by holding up a thread between the eye and the two ſtars, and extending it in ſuch a manner as it ſhall ſeem to croſs each ſtar: Then they look out two other ſtars in ſuch ſituation alſo, that the comet ſhall appear in a line that paſſes from one to the other, which are found as before. Then they extend a thread upon the celeſtial globe from one of the two firſt ſtars to the other. And another thread from one of the two laſt ſtars to the other; and the point on the globe where the threads croſs, is the apparent place of the comet at the time the obſervation was made.

This they do daily, and ſo trace out its apparent courſe in the heavens.

I ſhall now proceed to acquaint the reader with the zodiac of comets. Caſſini hath obſerved a certain track in the heavens, within whoſe bounds (by many obſervations) he hath found moſt comets, though not all, to keep. This he makes as broad as the other zodiac, and marks it with ſigns or conſtellations like that, which are Antinous, Peſagus, Andromeda, Taurus, Orion, the leſſer Dog, Hydra, the Centaure, Scorpion, and Sagittary.

The benefit which the world may expect to receive from the appearance of comets. Some of them have their nodes ſo very near the annual orb of the earth, that if it ſhall ſo happen, that the earth be found in the parts of her orb next the node of ſuch a comet, whilſt the comet paſſes by, as the apparent motion of the comet will be incredible ſwift, ſo its parallax will become very ſenſible, and the proportion thereof to that of the ſun will be given. Wherefore ſuch tranſits of comets do afford us the very beſt means, tho' they ſeldom happen, to determine the diſtance of the ſun and earth, which hitherto has only been attempted by Mars in his oppoſition to the ſun; or elſe Venus in perigæo, whoſe parallaxes, tho' triple to that of the ſun, are ſcarce any ways to be perceived by our inſtruments; whence we are ſtill in great uncertainty in that affair.

This uſe of comets was the ingenious thought of that excellent geometrician Mr Nicholas Fatio.

Now the comet of 1472 had a parallax above twenty times greater than the ſun's. And if the comet of 1618 had come down about the middle of March to his aſcending node, or if that of 1684 had arrived a little ſooner at its aſcending node, they would have been yet much nearer the earth, and conſequently have had more notably parallaxes. But hitherto none has threatned the earth with a nearer appulſe than that of 1680; for by calculation, it was found that Nov. 11, at 1 h. 6 m. p. m. (or 6 minutes paſt one in the afternoon) that comet was not above the ſemi-diameter of the ſun to the northward of the way of the earth: At which time, had the earth been there, the comet would have had a parallax equal to that of the moon.

But theſe benefits may be attended with great diſadvantages, if not timely prevented by the hand of providence; for had the aforeſaid comet come towards the ſun thirty-one days later than it did, without doubt by its centripetal force, it would have produced ſome change in the ſituation and ſpecies of the earth's orbit, and in the length of the year. But may the great good God avert a ſhock or contact of ſuch great bodies moving with ſuch forces, (which however is manifeſtly by no means impoſſible) leſt the moſt beautiful order of things be entirely deſtroyed and reduced to its ancient chaos.—This was remarked by our ſagacious author.

It would prove an endleſs taſk, to recount all the conjectures advanced in relation to comets. Mr Whiſton, in his theory of the earth, makes it very probable that the univerſal deluge was occaſioned by a comet. He ſuppoſed the earth to move at firſt in a circular orbit, but by the effect of a comet as it paſſed by, which not only occaſioned a ſtupendous tide in the abyſs, which was under the upper cruſt of the earth and in the ſmall ſeas, (for he allows no great ocean there, as in ours) which breaking out, and overflowing, ſwallowed up the antediluvian earth, but alſo by the power of gravitation, drew the earth from a circular to an elliptical orbit. That the moon was then in ſuch a place of its orbit as to be equally attracted by the earth when the comet paſſed by.

He ſuppoſes that the forty days rain, mentioned by Moſes, was cauſed by the comet's tail; for the comet, in its appulſe towards the earth, came ſo near it as to involve it in its atmoſphere and tail for a good while, and conſequently left a vaſt quantity of vapours both expanded and condenſed on its ſurface, a great part of which being very much rarefied after their firſt fall, would ſoon be drawn up into the air again, and afterwards fall down to the earth in vaſt and prodigiouſly violent rains.

But the other great rain, which with this, laſted for one hundred and fifty days, was cauſed, he ſaith, by the earth's coming a ſecond time into the tail of the comet: And from this double coming of the earth into firſt the atmoſphere, and then the tail of the comet, he ſuppoſes half the water of the deluge to be derived, as the other half came, from the abyſs, whoſe waters he ſuppoſes were continued to be brought out from the preſſure of the water which came from the comet, which he thinks would preſs downwards with a mighty force, and endeavour to ſink the outward cruſt of the earth down into the abyſs, and this would force the ſubterraneous water up through the clifts and fiſſures before-made in the cruſt, by the violence of the tide above-mentioned.

From the calculation of this comet he concludes, that the deluge began on the 17th day of the ſecond month from the autumnal equinox, (or on the 27th day of November in the Julian ſtile extended backward) in the 2365th year year of the Julian period, and in the 2349th year before the Chriſtian æra.

How he makes out theſe things, the reader will find in his New Theory of the Earth, which is very well worth the careful peruſal of every mathematical and philoſophical reader.

Some philoſophers are of opinion, that comets in their ſeveral revolutions approach nearer and nearer to the ſun, till at laſt they fall into, and ſupply the ſun with freſh fuel, fire and heat. But how comets ſhould do this, without they conſiſt of a very combuſtible matter of a much larger bulk, and made much quicker returns, is not very eaſy to conceive.

Some alſo imagine that by the rarefaction and ſpreading of the vapours of the tails of comets, they ſupply the planets with moiſture, which they ſuppoſe continually decreaſes by vegetation, putrifaction, &c.

Sir Iſaac Newton was likewiſe of this opinion. He obſerves that all vegetables do entirely grow and encreaſe from liquors, and then, as to their greateſt part, do turn by putrifaction into dry earth, and a ſlime perpetually is precipitated to the bottom of putrifying liquors. From hence the quantity or bulk of dry earth muſt continually increaſe, and the liquors or moiſture of our globe continually decreaſe, and at laſt be quite evaporated and loſt if they had not as continual a ſupply from ſome part or other of the univerſe. And I do chiefly ſuſpect, ſaith our author, that that ſpirit which is the fineſt, ſubtileſt, and beſt part of our air, and which is neceſſarily requiſite to the liſe and being of all things, comes chiefly from comets.

Others think they are appointed as places of torment for the damned, that is, each comet is properly and literally ſpeaking a hell; from the intolerable and inconceivable heat and cold which is found alternately in thoſe bodies.

Theſe conjectures have probably riſen from an opinion of ſome others, who imagined the ſun itſelf to be a hell or place of torment. But by the way it makes no matter whether this place of torment ſinners are threatned with be a lake of fire, or ſome other kind of puniſhment as hard and terrible to endure, ſince the ſcripture ſometimes ſpeaks in parable.

CHAP. V.

Of the Invention of the Zodiac.

THE inhabitants of Chaldea are allowed the honour of the invention of the zodiac, though ſome aſcribe it to the Egyptians: they both were people that delighted much in aſtronomy, and both were fathers of all the race of men ſince the deluge. They remarked, that the ſun, with the whole heavens, daily turned and paſſed from eaſt to weſt; and, at the ſame time, they obſerved that the ſun, by a motion peculiar to itſelf, daily withdrew from certain ſtars, and placed himſelf under others in his progreſs to the eaſt; that the moon 12 times finiſhed the ſame courſe to the ſun's once, and began the 13th before the ſun had entirely gone through it. The cuſtom of dividing the year pretty nearly into twelve moons, made men deſirous of having twelve parts of the year exactly equal among themſelves, or twelve months exactly equivalent to the year itſelf, by which they might be able to point out in the heavens, by ſhewing the particular ſtars, under which the ſun paſſed every month. They divided the ſun's rout into twelve equal parts, or collections of ſtars, which they called conſtellations: Thus our Chaldeans took two copper veſſels, both uncovered; one of them pierced at the bottom, the other not: Having ſtopped the hole of the former, they filled it with water, and placed it ſo, that, at the turning of a cock, the water might diſcharge itſelf into the latter. After this they obſerved on that part of the heavens, which the ſun annually traces, the riſing of a ſtar, remarkable for either magnitude or brightneſs; and, the inſtant it appeared on the horizon, they began to diſcharge the water contained in the upper veſſel, letting it run the remainder of all that night, the day following, and to the very moment that the ſame ſtar, returning to the eaſt, appeared again. The inſtant it was diſcovered they removed the under veſſel, and threw away the water remaining in the upper.

The obſervers were certain, that they had the whole revolution of the heavens between the time of the firſt and ſecond riſing of the ſtar: Wherefore the water which had emptied itſelf into the under veſſel, during that ſpace, afforded them an exact method to meaſure the time of one revolution of the heavens, and to divide this ſpace into twelve equal parts; for, by dividing this water into twelve ſuch, they were certain to have the revolution of the 12th part of the heavens, in running off of this 12th part of the water; wherefore they divided the water of the under veſſel into twelve parts, exactly equal, and prepared two ſmaller veſſels, each capable of receiving and containing one of thoſe parts compleat, and no more. They then threw the whole quantity of water once more into the large veſſel, keeping the cock ſhut; after which they placed one of theſe ſmaller veſſels under the cock, and the other near it, to ſucceed to its place when the firſt was filled.

Having made theſe preparations the following night, they obſerved that part of the heavens, towards which they had long remarked that the ſun, moon, and planets directed their courſe, and waited the riſing of the conſtellation, ſince named Aries, or the ram. It is poſſible the Greeks have, in proceſs of time, given this name to other ſtars than thoſe which bore it ſoon after the deluge ; but that inquiry is not needful here. The moment the Ram appeared, and that they ſaw his firſt ſtar ariſe, they let the water run into the ſmaller veſſel, which, when it was full, they took away, and poured out, putting, that inſtant, the other in its place. They obſerved with great exactneſs, and ſo as to remember all the ſtars that aroſe during the time the veſſel was filling ; and this part of heaven was terminated in their obſervation, by the ſtar which laſt appeared on the horizon, the moment the meaſure was exactly filled ; ſo that allowing time for theſe two ſmall veſſels to be alternately filled to the brims, each of them three times in the ſpace of the night, they, by this method, had one half of the ſun's rout, the exact half of the heaven itſelf ; and this half, divided into ſix equal parts, of which they could ſhew and diſtinguiſh the beginning, middle, and end, by ſuch ſtars as are eaſy to be known again, either by their magnitude, number or diſpoſition. As to the other half of the heavens, and the other ſix conſtellations, which the ſun paſſes through, they were obliged to refer their obſervations to another ſeaſon.

They waited till the ſun, being placed in the midſt of the conſtellations, already obſerved and known, afforded them the liberty to ſee thoſe others in the night. Being certain by this, or ſome other equivalent invention, of the great annual courſe which the ſun regularly keeps in the heavens, and of the equality of thoſe ſpaces which the conſtellations take up that bound his courſe, the obſervers thought of giving them names. They, in general, called them the ſtations or houſes of the ſun, and aſſigned three to each ſeaſon ; they afterwards diſtinguiſhed every conſtellation by a particular name, by which they not only deſigned to make them reſpectively known to the people, but alſo, at the ſame time, to declare to them ſuch quality of the year as regardeth the whole ſociety, when the ſun reached ſuch a conſtellation.

It muſt be obſerved, that the names by which the twelve conſtellations in the zodiac are diſtinguiſhed, were drawn from the moſt important events, occurring either in the heavens, or upon the earth, as the ſun poſſeſſes his ſtation under every one of them ſucceſſively.

By a viſible care of providence, the dams of the flocks are commonly with young about the latter end of autumn. They are delivered of their burthens in winter, and entrance of the ſpring. The young are kept from the ſeverity of the ſeaſon, by the warmth of their dams, during the cold ; and quit them, without reluctance, at the return of warm weather. Lambs are firſt brought forth ; after theſe, calves ; and laſtly, kids : Thus the lambs get ſtrength ſufficient to follow the ram into the fields, when fine weather begins ; ſoon after, the calves and kids begin to ramble, and increaſing the flocks and herds, augment the revenue of their owner. Our Chaldean obſerves, knowing nothing, produced during the ſpring, more uſeful than lambs, calves, and kids, impoſed the appellations of theſe three animals, which enrich the ſociety, on the conſtellations, under which the ſun paſſes during this ſeaſon.

Spring conſtellations.

The firſt they named Aries, or the ram ; the ſecond, Taurus, or the bull ; and the third, Gemini, or the two kids, to indicate the fecundity of goats, which oftener bring forth twins than one, and afford a quantity of milk more than ſufficient for their nouriſhment.

Summer conſtellations.

The whole race of men, being united in the plains of Irac, had often obſerved, that the ſun drew towards them, he roſe to a certain height or point, which he did not go beyond; and that, as he retired from them, he deſcended, day by day, for the ſpace of ſix months, till he had reached another point much lower than the former, but did not paſs beneath it: This retreat of the ſun, which was performed very ſlowly, gave the obſervers occaſion to call the ſtars which follow the kids, or gemini, by the name of Cancer, or the crab, as that animal goes backward. When the ſun paſſes under the next conſtellation, it makes us ſenſible, even in our climes, of violent heats; but they are much more intenſe where mankind was then aſſembled. If the poets have attributed to this conſtellation all the rage and fury of Leo, or the lion, which is the name it is known by, it is not difficult to perceive what determined the choice of that name from the earlieſt times.

Soon after the harveſt, both of hay and corn, is entirely finiſhed in the eaſt, and nothing left upon the ground but a few ears, which they cauſe the moſt uſeleſs hands to gather: little girls are employed in this work. Could then a more proper name be adapted to the conſtellation, under which the ſun can diſcover no harveſt, than Virgo, or the young female-gleaner? Thoſe wings, which we ſee in the globes, are ornaments of later date ſince the introduction of fables. The virgin that follows the lion, is certainly no other than a gleaner or reaper, which you will ſee, and leſt ſhe might be miſtaken for the other, ſhe carries in her hand a bundle of ears of corn, which is a natural proof of the origin I have given her.

Autumnal conſtellations.

The exact equality of the days and nights, which happen on the ſun's leaving Virgo, gave the next ſign the name of Libra, or the ballance. The frequent diſtempers the ſun either leaves or occaſions at this time, by his retrent, was the reaſon of giving to the following ſign, the name of Scorpio, or the ſcorpion, becauſe he is a noxious animal, and draws both his ſting and venom after him. Towards the end of autumn, the fall of the leaf expoſes the wild beaſts to view. The vintage is over, and all the fruits of the earth gathered in. The fields are all open, and it is of dangerous conſequence to ſuffer the increaſe of beaſts on the winter's approach. Every thing invites the ſportſman out, and the ſign in which the ſun then is, has, therefore, taken the name of Sagittarious, the archer or huntſman.

Winter conſtellations.

The nature of the wild goat or capricorn, which the firſt winter ſign is called, is to ſeek its ſuſtenance in ſearching from the foot to the ſummits of the higheſt mountains, climbing from rock to rock: Wherefore, the name of this animal was very proper, to acquaint men with the very minute that the ſun was declined to its loweſt boundary; that he was going to aſcend again to the higheſt point of his career, and that he would continue thus aſcending for ſix ſucceſſive months. This is a direct contraſt to the crab, and this lucky oppoſition of characters, ſhews by what the firſt obſervers were directed in the impoſing the fore-mentioned names.

Aquarius and Piſces plainly denote a rainy ſeaſon; and that time of the year, when the fiſh, being more in their prime than any other, afford both profit and pleaſure of fiſhing. Of the twelve conſtellations, it may be obſerved, that often their names are borrowed of animals; whence it comes that the annual circle, which they compoſe, has taken the name of Zodiac, or circle of animals: (for zodiac comes either from zoe, which in Greek ſignifies life; or from the Greek zodion, a beaſt; but it rather ſeems to be derived from the former, becauſe all living creatures, which were painted therein, were not beaſts.) By this ingenuity, men obtained a new method for the menſuration of time, and the regulation of all their labours. They before knew, without trouble or care, how to ſettle the order of their feaſts and common occurrences, by the phaſis of the moon, without other aſſiſtance.

In acquiring the knowledge of the zodiac, they alſo obtained a certain one of the year.

The conſtellations were, as well by their names as by their reſpective ſituations, real marks, by which they knew the order of their gathering in the different fruits of the earth, and by which they were taught what was neceſſary to be done towards the forwarding of their harveſt, as theſe ſigns ſhewed them at what diſtance of time it was to be expected. The people were neither under a neceſſity of reckoning the days, nor of ſetting down the order of times for their government.

Twelve words, adapted to twelve different parts of the heavens, was a ſcience as uſeful and advantageous to them, as it was eaſy to be acquired. When, after ſun-ſet, they ſaw the ſtars, which compoſe the Ram, appear above the oppoſite horizon, half the heaven's diſtant from the ſun, they knew that the bright planet was then under the ſign of the ballance; which being the ſeventh of the celeſtial ſigns, was diſtant from the firſt of them the whole half of the zodiac. When, towards the approach of day, they ſaw the brighteſt ſtar of the lion in the middle of the heavens, equally diſtant from eaſt and weſt, they very readily conceived, that the ſun, which was near riſing, was at the diſtance of three ſigns from the lion, and removed one quarter of his circle towards the eaſt. Thus, without ſeeing the ſtars, which the ſun, paſſing under, hid by his brightneſs, they could tell you, with certainty, the ſun was now in the bull; two months hence we ſhall have the longeſt days, &c. They could, by ſeeing one ſingle conſtellation, either in the eaſt, the middle, or in the weſt of the heavens, inſtantly tell you where the ſun was, how far the year was advanced, and what buſineſs was proper to take in hand.

The firſt race of men, having no writing, read in the heaven, what works they ſhould go upon, or the courſe of the year.

But even this uſeful invention of writing is the product of aſtronomy; and it is nothing difficult to evince, that the giving names to the twelve celeſtial ſigns, produced the invention of painting and writing. This account diſcloſes to us an agreeable novelty, and will continue to diſcover how much we owe to the ſtudy of nature.

Invention of writing.

It is evident that painting preceded writing; aſtronomy gave birth to the former, and, in proceſs of time, both concurred to diſcover the art of writing. Eight figures in the zodiac have ſuch an evident relation to the animals, or the objects whoſe names they bear, that it cannot be doubted that they are their real pictures. The firſt letter, A, is a ſketch of the rams horns; the ſecond, B, is apparently the fore part of the bull's head; the third, C, is an uniting of the two heads of the kids; the ſeventh, G, is nothing but the beam of the ballances; the eighth, H, is a haſty ſketch of the paws, long tail, and ſting of the ſcorpion; I, the ninth, is the arrow of the archer, whoſe name it bears; L, the eleventh letter, repreſents a ſtream of water; and the twelfth, M, two fiſhes, back to back. Theſe four others, D, E, F, K, probably, at firſt, equally like their objects, may have been alter'd either by time, or the neceſſity of abridging them.

I

I dare not aver that theſe current abbreviations are from firſt antiquity; but the entire celeſtial ſigns being often found depicted in Egyptian monuments, which are known to have been ſoon after the flood, we may from thence judge of the antiquity of the zodiac, and of the manner it was figured to the people. This painting was the beginning of writing, ſince a figure ſhewn to the eye gave an idea of ſomething more: This uſeful invention extended itſelf by degrees. The Egyptian Thot invented other ſymbols, relative to the affairs or to the peculiar productions of Egypt. The mark or the character of the ſun, which governs the courſe of nature, was an armed man, with a whip in his hand, as a charioteer, or elſe adorned with a ſcepter, as a king; and this figure was call'd Oſiris, that is, the leader, inſpector, or king.

A	♈
B	♉
C	♊
G	♎
H	♏
I	♐
L	♒
M	♓
D	♋
E	♌
F	♍
K	♑

The earth, which produces all things, and is inceſſantly varying her productions, was repreſented under the ſymbol of a fruitful woman, whoſe attributes were varied according to the feſtivals or works, which were deſigned to be proclaimed. This figure was named Iſis, that is, the woman, or queen. The creſcent, which was the token of the Neomenia, or aſſembly of people, being placed on her head, with ſuch or ſuch other attribute, might ſerve to denote the aſſembly of ſuch or ſuch a ſeaſon. The ſplendid dog ſtar, which begins to ſhew itſelf in the morning before the aurora, and to diſengage itſelf from the ſun when that planet is under the ſign of the lion, was the never failing token of the time in which the Nile overflows its banks; it warned the Egyptians to be ſpeedy in their retreat to the upper grounds, to make proviſion for their ſuſtenance, and to prevent ſurprize; doing them the ſervice of that animal, who gives his maſter notice of the approach of robbers; and it is for that very reaſon they repreſented it under the figure of a dog, or under a human figure with a dog's head, wings at the feet, and a kettle on its arm. The people eaſily underſtood this language, by which was figured to them the repoſe and inaction of their retreat, while the inundation continued, which would laſt all the time that the ſun continued under the ſign of the lion; and virgo was repreſented by a ſphinx, compoſed of a virgin's face, and the body of a lion couchant, fixed on the borders of terraſſes in a conſtant inactive attitude. It very much concerned the Egyptians to be acquainted with the returns and duration of the Eteſian winds, which collected the vapours in Æthiopia, and by blowing from north to ſouth about the latter end of the ſpring, cauſed the inundation. It was afterwards of moment, to learn the return of the ſouth wind, which contributed to the draining the waters off towards the Mediterranean. But how were theſe winds to be painted? To this end they made choice of a bird, which was the hawk:* This bird turning towards the ſouth, ſtretches his wings to renew his plumage upon the coming of great heats; and this was to repreſent the Eteſian winds which blew from north to ſouth. And the ſymbol of the return of the ſouth wind, proper for carrying off the waters, was the hoop, another bird which comes from Æthiopia, to ſeek for worms in the ſlime of the Nile, after the waters are run off. Theſe few examples may give an idea of the ſymbolical writing of the Egyptians, as it was pecular to them, by the extenſive uſe they made of it;

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* Job. xxxix. 26.

but the invention of the zodiac, which gave ground to it, is more ancient than the colony of Egypt, and comes ſrom the plains of Senaar: For had the Egyptians been the firſt authors of the celeſtial ſigns and names, they would never have placed the figure of a ſemale gleaner after the ſign of the lion, to denote the harveſt; ſor tho', at this time, it is over in other places, it is not near in Egypt, the country being then all under water. In Egypt they do not put their ſeed into the ground till November is pretty far advanced, and they reap in March or April; ſo that their corn takes no more than four months to ripen.

This ſymbolical writing, the firſt product of aſtronomy, was made uſe of to inſtruct the people in all manner of truths, in all opinions, and in all neceſſary works; but it became troubleſome by the multiplicity of figures and attributes, which increaſed in proportion to the number of objects; an inconvenience found in the Chineſe writing, for they have a diſtinct mark for every particular figure. A great genius, whoſe name hiſtory does not mention, but who lived before Moſes, and is very different from Cadmus, to whom the Greeks give the honour of this invention, obſerving that the ſounds and articulations of the voice, with which we expreſs all things, are but few in number, thought of repreſenting theſe ſounds and articulations by the ſame number of characters, which do not exceed twenty-four.

This writing, which by repreſenting the ſound of the voice, has power to expreſs all the thoughts and objects, which are uſed to be denoted by thoſe ſounds, appeared ſo plain and fertile, that it was immediately embraced, and extended itſelf into all parts. It became the cuſtomary way of writing, and cauſed ſo great a neglect of the ſymbolical, that, by degrees, the uſe of it was loſt, and its ſignification entirely forgot.

But numerous ſymbols, exhibited on public monuments, in places of worſhip, and ceremonials of feaſts, which were unchangeable, and rendered ſacred by antient uſe, being frequently expoſed to the people's view, they, ignorant of the meaning, ſtupidly conſidered the emblematical figure, and carried their enquiry no further. They had a confuſed notion that thoſe emblems had relation to the ſun, winds, ſeaſons, and different parts of heaven; to account for which, they had recourſe to hiſtorical interpretations and fabulous ſtories, which drew them into idle conceits: From hence, my author makes it probable, that this was the ſole occaſion of heatheniſm and idolatry. Vide *Spectacle de la Nature*, vol. iv. p. 140.

CHAP. VI.

Of the Equation of Time.

EQUATION of time, in aſtronomy, is the reduction of the apparent motion of the ſun, to equable, mean, or true time. The difference between the true and apparen time, ariſes from two cauſes, the excentricity of the earth's orbit, and the obliquity of the ecliptic: Thus, the natural day is meaſured not only by one entire converſion of the equinoctial, or 24 equinoctial hours (which is indeed taken to be performed in equal times) but increaſes by ſo much, as anſwers to that part of the ſun's, or earth's annual motion, as is performed in that time: For, when that part of the equinoctial, which (with the ſun) was at the meridian yeſterday at noon, is come thither again to-day, it is not yet noon; becauſe the ſun is not now at the place where yeſterday he was, but is gone forward about one degree, more or leſs; but we muſt ſtay till that place where the ſun now is come to the meridian, before it be now noon. This additament (above the 24 equinoctial hours, or entire converſion of the equinoctial) is, upon a double account unequal: Firſt, becauſe the ſun, by reaſon of its apogæum and perigeum, doth not, at all times of the year, dipſatch, in one day, an equal arch of the ecliptic; but greater arches near the perigeum, which is about the middle of December, and leſſer, near the apogæum, which is about the middle of June: Secondly, tho' the ſun ſhould, in the ecliptic, move always at the ſame rate, yet equal arches of the ecliptic do not, in all parts of the zodiac, anſwer to equal arches of the equinoctial, by which we are to eſtimate time; becauſe ſome parts of it, as the two ſolſtitial points, lie nearer to a parallel poſition to the equinoctial than others; as theſe about the two equinoctial points, where the ecliptic and equinoctial do interſect; whereupon an arch of the ecliptic, near the ſolſtitial points, anſwers to a greater arch of the equinoctial, than an arch equal thereto near the equinoctial points.

If you imagine another ſun to move in the heavens in an equal emotion, not in the ecliptic, but in the equinoctial, the difference between their coming to the meridian every day (or to any one and the ſame hour circle) will be the equation of time; and, becauſe the true ſun, and that point of the equator, where his right aſcenſion ends, come always to the meridian together, the equation of time may be defined to be that ſpace of time which is paſſed over, while an arch of the equator comprehended between the extreme points of the true ſun's aſcenſion, and the place of the feigned ſun, paſſes over the meridian: And if this arch be turned into time, it gives the true equation of time.

Again, as the motion and time meaſured by the ſun, in the equinoctial, is always equal, it follows, that the time meaſured by the ſun, in the ecliptic, muſt be always unequal; or, in other words, the ſolar days are ſometimes ſhorter and ſometimes longer than the equal times meaſured out in the equinoctial. As the true motion of the earth precedes its mean motion in the firſt ſemi-circle of anomaly, and is preceded by the mean in the ſecond, it follows, that while the earth is going from the aphelium to the perihelium; or, while the ſun apparently moves from the apogœum to the perigeum, the apparent time will be before the mean; and, in the other ſemi circle of anomaly it will be after it.

The difference of theſe motions, converted into time, is the equation of time in this reſpect, and is to be ſubſtracted from the apparent time to gain the mean, or added to the mean to gain the apparent, in the firſt ſemi-circle of anomaly, and, *vice verſa*, in the latter; both theſe parts, of the equation of time, are calculated, by aſtronomers, for every degree of the ſun's longitude in the ecliptic, and diſpoſed in tables with directions for adding or ſubſtracting, as the caſe requires, by which means the true equal time may at all times be had. From what has been ſaid, it appears, that the apparent time, or that ſhewn by the ſun-dial, is the ſame with the mean, or equal time, ſhewn by a good clock or watch, viz. about April 15, June 17, Auguſt 31, and December 24, according to the following account, which may ſerve as a rule;

The fifteenth of April,
And 17th of June remember;
Auguſt the thirty-firſt,
And 24th of December.
On theſe four days, and none elſe in the year,
The ſun and the clock both the ſame time declare.

It is alſo remarkable that about the third of November, the equation is greateſt of all clocks, being then about 16 minutes and 13 ſeconds ſlower than ſun-dials. As therefore the ſolar days are unequal, hours muſt be ſo of courſe; and, according as the above-mentioned cauſes, which are independent on each other, concur or counter-act each other, this inequality is more or leſs. Beſides, as the former of theſe cauſes, viz. the excentricity of the earth's orbit, is affected by the preceſſion of the equinoxes, tables of the equation of time, made for any year, muſt continually afterwards deviate more and more from the truth; yet, as this variation is extremely ſlow, the ſame tables may very well ſerve for an age or more, without any ſenſible error.

Here follows a table of the equation of time, calculated for the new or gregorian ſtile, and ſhewing how much equal or true time is faſter or ſlower than apparent time, for every day throughout the year; or which comes to the ſame thing, how many minutes and ſeconds a good clock or watch is faſter or ſlower than a good ſun-dial.

The

The TABLE.

	Jan		Feb.		March		April		May		June		July		Auguſt		Sept:		Oct.		Nov.		Dec.	
Days	Faſter		Faſter		Faſter		Faſter		Slower		Slower		Faſter		Faſter		Slower		Slower		Slower		Slower	
	'	"	'	"	'	"	'	"	'	"	'	"	'	"	'	'	'	"	'	"	'	"	'	"
1	4	6	14	13	12	48	4	1	3	8	2	47	3	8	5	46	0	18	10	23	16	13	10	32
2	4	34	14	10	12	36	3	43	3	16	2	38	3	19	5	42	0	36	10	42	16	3	9	49
3	5 Equal time faſter as far as two aſteriſks.	2	14	27	12	29	3	25	3	23	2	29	3	31	5	38	0 Equal time ſlower as far as the next two aſtericks.	55	11	0	16	13	9	45
4	5	30	14	32	12		3	6	3	30	2	19	3	42	5	33	1	14	11	18	16	12	9	20
5	5	57	14	37	11	55	2	48	3	36	2	9	3	52	5	28	1	34	11	36	16	10	8	55
6	6	24	14	41	11	41	2	30	3	42	1	59	4	2	5	22	1	54	11	53	16	8	8	29
7	6	50	14	44	11	26	2	13	3	47	1	48	4	12	5	15	2	14	12	10	16	4	8	3
8	7	16	14	47	11	11	1	55	3	51	1	37	4	22	5	8	2	34	12	37	16	0	7	37
9	7	41	14	48	10	56	1	38	3	55	1	26	4	31	5	0	2	54	12	43	15	54	7	10
10	8	6	14	49	10	40	1	21	3	58	1	14	4	40	4	52	3	14	12	58	15	48	6	42
11	8	30	14	49	10	24	1	4	4	0	1	2	4	48	4	43	3	35	13	13	15	41	6	14
12	8	59	14	48	10	7	0	48	4	2	0	50	4	56	4	34	3	55	13	28	15	34	5	46
13	9	22	14	47	9	50	0	32	4	4	0	38	5	4	4	24	4	16	13	42	15	25	5	18
1	9	44	14	44	9	33	0	16	4	5	0	26	5	11	4	13	4	37	13	56	15	16	4	49
15	10	5	14	41	9	16	0 ** Equal time ſlower to the next aſteriſks.	1	4	5	0	13	5	17	4	2	4	58	14	9	15.	6	4	19
16	10	26	14	37	8	58	0	14	4	5	0 ** Equal time faſter to the next aſteriſks.	1	5	23	3	50	5	19	14	22	14	55	3	50
17	10	46	14	33	8	40	0	29	4	4	0	12	5	29	3	38	5	40	14	33	14	43	3	20
18	11	5	14	28	8	22	0	43	4	2	0	25	5	34	3	26	6	1	14	45	14	30	2	51
19	11	24	14	22	8	4	0	57	4	0	0	38	5	39	3	12	6	22	14	56	14	16	2	21
20	11	42	14	15	7	46	1	11	3	58	0	50	5	43	2	59	6	42	15	6	14	2	1	51
21	11	59	14	8	7	27	1	24	3	55	1	3	5	46	2	45	7	3	15	15	13	46	1	20
22	12	15	14	0	7	9	1	37	3	51	1	16	5	49	2	30	7	24	15	24	13	30	0	50
23	12	30	13	52	6	50	1	49	3	47	1	29	5	51	2	15	7	44	15	32	13	13	0 ** Equal time faſter.	20
24	12	45	13	43	6	31	2	1	3	42	1	42	5	53	2	0	8	5	15	40	12	56	0	10
25	12	59	13	33	6	13	2	12	3	37	1	55	5	54	1	44	8	25	15	46	12	28	0	40
26	13	12	13	22	5	54	2	23	3	31	2	7	5	55	1	18	8	45	15	52	12	18	1	10
27	13	24	13	12	5	35	2	33	3	25	2	20	5	55	1	11	9	5	15	58	11	58	1	40
28	13	36	13	0	5	16	2	43	3	18	2	32	5	54	0	54	9	25	16	2	11	38	2	10
29	13	46			4	57	2	52	3	11	2	44	5	53	0	36	9	45	16	6	11	17	2	39
30	13	56			4	39	3	0	3	3	2	56	5	51	0	19	10	4	16	9	10	55	3	8
31	14				4	20			2	55			5	49	0 **	1			16	11			3	37

A SYNOPSIS of the chief Properties of the PLANETS.

TITLES.	SATURN.	JUPITER.	MARS.	EARTH.	VENUS.	MERCURY.	SUN.	MOON.
	y. d.	y. d.	y. d.	d. h. m.	d. h.	d. h.		d. h. m.
Periods —	29 167	11 315	1 322	365 6 9	224 17	87 23		27 7 43
		h. m.	h. m.	h. m.			d. h.	
Diurnal revolutions	Not known.	9 56	24 40	23 56	23 0	Not known	25 6	27 7 43
Mean dis. from ſun, mil.	777000000	424000000	123000000	81000000	59000000	32000000		
Diameters in miles	93450	130600	4875	7970	7906	4240	763000	2175
Proportion of bulk	161	4400	$\frac{1}{4}$	1	$\frac{39}{40}$	$\frac{1}{7}$	878000	$\frac{1}{30}$
Quantity of matter	126	827	Not known	1	Not known.	Not known.	228700	$\frac{1}{40}$
Gravity on the ſurface	92	308		1			24	34
Inclinat. of the orbits	2° 30′	1° 20′	1° 52′	0° 0′	3° 24′	6° 54′		5° variable
Inclination of the axes		Very little	0° 0′	23° 29′	75° 0′		8° 0′	3° 10′
Propor. of light & heat	$\frac{1}{100}$	$\frac{1}{28}$	$\frac{3}{7}$	1	$1\frac{3}{4}$	$6\frac{1}{2}$	4500	Variable
Velocity, miles an ho:	19000	25400	47240	58050	68040	92700		2300
Place of aſcend. node	Cancer 22°	Can. 8°	Taurus 19°		Gemin. 15°	Aries 15°		Variable
Place of the aphelium	Sagit. 28°	Libra 9°	Virgo 1°	Cap. 8° 25′	Aquar. 5°	Sagit. 13°		Variable
Excentricities, miles	44320000	20440000	108112000	1368600	606400	6634000		Variable
Mean mot. in the eclip.	0° 2′ 0″	0° 4′ 59″	0° 31′ 27″	0° 59′ 8″	1° 36′ 8″	4° 5′ 32″		13° 10′ 35″

Satellites of Saturn.	Per. round Saturn.	Diſt. from Saturn, miles	Satellites of Jupiter.	Per. round Jupiter.	Diſt. from Jupit. miles.	From the earth to the moon
	d. h. m.			d. h. m. ſ.		240000 miles.
1	1 21 19	202800	1	1 18 28 36	363600	
2	2 17 40	259700	2	3 13 17 54	580000	
3	4 12 27	362900	3	7 3 59 36	925000	
4	15 22 41	841000	4	16 18 5 12	1630000	
5	79 22 0	2463000				

CHAP. VII.

A Synopſis of the chief Properties of the Planets, ſhewing the Uſe of the foregoing Table.

THE names of the primary planets, viz. Saturn, Jupiter, &c. are ſhewn at the head of the table, together with the ſun and moon.

The firſt line ſhews the periods of the planets, that is, the times they take up in going round the ſun, or the center of their reſpective orbits: For example, Saturn goes round the ſun in 29 years, 167 days; Jupiter in 11 years, 315 days. The moon goes round the earth in 27 days, 7 hours, and 43 minutes, &c. The period of a planet is found by obſerving the time it takes up, in going from a fixt ſtar, and returning to it again.

If the planets be inhabitable worlds, this line alſo ſhews the length of their years; thus, the length of a year to the inhabitants of Saturn (if any) is equal to 29 years, 167 days, as above; to Jupiter's, 11 years, 315 days, &c.

The next line ſhews the times of their diurnal revolutions, that is, the times they take up in turning round their reſpective axis; hence may you know the length of the day to the inhabitants of any planet, except the ſun, which is only a globe of fire furniſhing the reſt with light and heat. Example: Saturn is not known; Jupiter turns round his axis in 9 hours, 56 minutes, which is conſequently the length of the day to the inhabitants of that planet, and ſo of the reſt.

The diurnal revolution of a planet is found by obſerving the motion of the ſpots, which are found upon its ſurface; as for inſtance, if we look upon the ſun with a teleſcope, we ſhall ſee little black ſpots upon his diſk or ſurface, which always appear to move from eaſt to weſt, and come to the ſame poſition again in 25 days, 6 hours. Alſo Jupiter is obſerved to have a ſpot which paſſes over its diſk in about half the time mentioned in the table.

The third line ſhews the mean or middle diſtance from the ſun in miles; that is, Saturn is 777 millions of miles from the ſun; Jupiter is 424 millions, and ſo of the reſt as in the table.

The methods made uſe of to diſcover the diſtances of the planets are ſo many, and the practical part ſo difficult, that I ſhall not trouble my reader with their deſcription, but only obſerve in general, that whenever the diſtance from the ſun to any one of the planets is found, the diſtance of the reſt may be found, by the famous propoſition, firſt diſcovered by the ingenious Kepler, and demonſtrated by the immortal Sir Iſaac Newton, viz. the ſquares of the periodical times of the planets round the ſun, are to one another, as the cubes of their reſpective diſtances from the ſun.—The ſame law is obſerved by the ſecondary planets in their motions round their primary.

N. B. Any number multiplied into itſelf, its product is called the ſquare of that number; and if that ſquare be multiplied again by the ſame number, that product is called the cube of it.

From many obſervations made by different perſons in different parts of the world, aſtronomers have moſtly agreed, that the diſtance of the earth from the ſun is 81 millions of miles, and from this ſuppoſition the reſt are calclaculated as above. The diſtance of the moon from the earth is pretty certainly known to be 240000 miles.

In the year 1761, on Saturday June 6, N. S. about 6 in the morning, the planet Venus will paſs between the ſun and the earth; at which time the diſtance of the ſun may be pretty exactly known, and the dimenſions of the heavens more accurately determined than has hitherto been done, becauſe in this poſition it is nearer the earth than at other times; wherefore its parallax, and conſequently its diſtance, may be better determined than at any other time.

N. B. Parallax is that arch of a great circle paſſing through the zenith and true place of the planet, and intercepted between the true and apparent place; becauſe the true place is ſuppoſed to be beheld from the earth's center, but the apparent from the ſuperficies, and that difference is the angle of parallax.

The diſtance of the planets from the ſun, or from one another, being expreſſed by numbers, does not convey a true idea of thoſe immenſe diſtances, for which reaſon aſtronomers often have recourſe to other methods. Suppoſe therefore, a body was to be projected from the ſun, and to continue moving with the ſame velocity, or ſwiftneſs, that a 24 pounder does out of the mouth of a cannon, it would fly to Mercury in 7 years 221 days; to Venus in 14 years, 8 days; to the earth in 19 years, 91 days, 18 hours; to Mars 29 years, 85 days; to Jupiter in 100 years, 280 days; to Saturn in 184 years, 240 days; to the fixed ſtars in about 7600000 years.

Theſe numbers are eaſily calculated, upon a ſuppoſition that a ball goes 8 miles in a minute, as it does very near.

The next line ſhews the diameters of the planets in miles, of which Saturn is 93450 miles; Jupiter 130600 miles, &c.

The real diameters of the planets are calculated from their apparent diameters and diſtances; for, if the diſtance of any globe, and its apparent diameter be known, the real diameter may be found by the known rules of trigonometry.

The 5th line ſhews the proportion of bulk, or bigneſs compared with the earth; *e. g.* Saturn is 161 times as big as the earth, Jupiter is 4400 times as big as the earth, and ſo of the reſt.

Theſe numbers are calculated from the laſt, thus, divide the cube of the diameter of any planet by the cube of the earth's diameter, and the quotient ſhews how much that planet is greater than the earth: For the magnitudes of globes are as the cubes of the diameters.

Some philoſophers infer from the analogy of Jupiter's diameter in reſpect to our earth's, that its inhabitants are at leaſt ſixty feet high; nor is there any thing to be wondered at in this, ſince things are great and ſmall only by compariſon. But as I intimated before, none but the ſupreme Being knows of what ſpecies the inhabitants of theſe worlds are.

The next line ſhews the quantity of matter compared with the earth; for inſtance, Saturn contains 126 times as much matter as the earth, Jupiter 827, &c.—The quantity of matter in a planet is known by its attraction*, for all bodies attract at equal diſtances with a force proportionable to the quantity of matter they contain.——If the quantities of matter in the planets be divided by their bulks, the quotients will be to one another, as the denſities of the planets; therefore from the two laſt lines in the table, the denſities of the planets are as theſe numbers, viz. Saturn 0,72, Jupiter 0,188, the earth 1, the ſun 0,26, moon 1,25; whence the moon is the moſt denſe body, and Jupiter the leaſt denſe of all the planets.

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* The attractions of the planets are found by the motions of their ſecondary planets; for it is demonſtrated by Sir Iſaac Newton, that if a body revolves round another, towards which it is continually impelled or attracted, (the diſtance remaining the ſame) the ſquares of

The gravity on the ſurface of a planet, is the tendency of a body to the center of the planet when placed upon its ſurface. The force of this tendency in the table is compared with the earth; for inſtance, ſuppoſe a body, as a pound of lead, was placed upon the ſurface of Saturn, it would be attracted by him with a force expreſſed by 0,92, that is, with $\frac{92}{100}$ parts of the force it is attracted by the earth, &c.

The next line ſhews the inclinations of their axes, that is, how much their axes are leaning from a perpendicular to the plain of the ecliptic; this is meaſured in degrees and minutes as before.

N. B. The inclination of the earth's axis, being 23° 29′, cauſes thoſe viciſſitudes of ſeaſons which we on the ſurface of the earth have every year, as is eaſily and plainly ſhewn by the orrery; and the greater the inclination of a planet's axis is, the greater will be the alteration of ſeaſons in that planet. Whence you will obſerve, that in Jupiter and Mars there will be little or no alteration, but always equal day and night.

The orbits of the planets are thoſe paths which they deſcribe by their motions round the ſun: Theſe orbits are not all in one plane, but are variouſly inclined to one another, and to the plane of the ecliptic or the earth's orbit.

The quantity of this inclination is ſet down in the 8th line, *e. g.* Saturn's orbit is inclined to the plane of the ecliptic 2° 30′, Jupiter's 1° 20′, &c.

The nearer any body is to the ſun, the more it muſt be heated by it; and the light and heat which any body receives from the ſun, muſt be inverſely as the ſquare of its diſtance from it, as is evident from the leaſt conſideration; from which principle are calculated the proportions of the light and heat, which the planets receive from the ſun, in compariſon of the earth; as Saturn hath 100th part of light and heat the earth has, Jupiter a 28th part, &c.

Here we ſuppoſe that heat is inſeparable from light, but by many obſervations we find, there is ſomething in the nature of heat which is not well underſtood, and that there may be light without heat. Thus we find ſome places, particularly on the tops of ſome mountains near the equator, where the ſun's rays are very bright and glaring, and yet the air is extremely cold: And again, other places of a conſiderable latitude where the air is tolerably warm.

If heat does not depend upon the ſun's rays, the planets may be all of the ſame heat with the earth, ſo as to be habitable by ſuch animals as are on the earth; or if there be a difference in the modification of their atmo-

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the periodical times will be inverſely as the attracting force; but the ſquare of the periodical times are directly as the cubes of the diſtances. Therefore if the cubes of the diſtances of the planets, both primary and ſecondary, be divided by the ſquares of the periodical times, the quotients will be as the quantities of matter in the bodies round which the others revolve; and becauſe Mars, Venus, and Mercury have no ſecondary planets revolving round them, their quantities of matter cannot be known.

ſpheres, tho' heat ſhould depend on the ſun's rays, they may become habitable with ſuch creatures. But the reaſon of what is here aſſerted I humbly conceive is occaſioned by the convexity of the ſurface whereon the rays fall, for when they are reflected from ſuch ſurfaces they muſt of conſequence diverge; and the ſplendor is occaſioned by the interſecting of the deſcending and aſcending rays, which cauſe no great heat becauſe they recede from each other, whereas in the valley below the reflected rays converge, and cauſe heat more or leſs, as the rays concur or unite; this is demonſtrable to any who knows the nature of burning ſpeculums or burning glaſſes; nay every houſewife knows that placing a pewter diſh artfully oppoſite to the mouth of a bee-hive, augments the ſun's heat, and thereby cauſes the bees to riſe by ſwarms in the caſting ſeaſon.

If we know the diameters of the orbits of the planets, and the times they take up in compleating their periods, it will be eaſy to calculate how faſt the planets move, which I have here done, and ſet down in the title of velocities, miles an hour; for example, Saturn runs through 19000 in an hour, Jupiter 25400, the earth 58050, &c.

The velocities of the planets are inverſely as the ſquare roots of their diſtances from the ſun, from which principle the foregoing numbers may be calculated.

As the ecliptic line is the orbit or annual path of the earth, ſo each planet has its proper orbit, whoſe plane differs ſome few degrees from the plane of the orbit of the earth; ſo we muſt imagine one ſide of the orbit of each planet to be elevated a little, and the other ſide to be depreſſed, ſo as to make an angle with the plane of the ecliptic, and cut the ecliptic in two oppoſite points, which are called the nodes of the planets orbits. The aſcending node is that point where the planet croſſes from the ſouth to the north; its place in the ecliptic is ſet down in the table; *e. g.* the aſcending node of Saturn's orbit is 22 degrees of the ſign Cancer, &c.

Every planet by its motion round the ſun deſcribes an ellipſis, having the ſun in one focus, and the point which is at the greateſt diſtance from the ſun is called the aphelion; its place in the ecliptic is ſet down in the table; for inſtance, Saturn is at the greateſt diſtance from the ſun in 28 degrees of Sagittarius, Jupiter in 9 degrees of Libra, the earth in 8 degrees and 25 minutes of Cancer, &c. The earth enters Cancer on the 21ſt of June, and therefore on the 29th or 30th of June it will be at the greateſt diſtance from the ſun.

The next line ſhews the excentricities of the orbits of the planets in miles, that is, the diſtance from the ſun to the center of the orbit. If the excentricity be added to the mean diſtance (ſhewn in the 3d line from the top of the table) the ſum will be the greateſt diſtance of the planet from the ſun, and their difference is the leaſt: Example, the earth's mean diſtance is 81,000,000 miles, and the excentricity of its orbit 1,368,600 miles, their ſum is 82,368,600, the greateſt diſtance of the earth from the ſun, and their difference 79,631,400, the leaſt diſtance.

The numbers in the three laſt lines are calculated from the obſervations of aſtronomers. The laſt line ſhews the daily mean motion in the ecliptic: It is eaſily calculated from the firſt line in the table, for every planet deſcribes 360 degrees in the time it goes round the ſun.

The little columns at the bottom of the table ſhew the periods and diſtances of Saturn and Jupiter's ſatellites, or moons; they are plain from their titles.

CHAP.

CHAP. VIII.

Of the Celeſtial Appearances. An Account of the Sky or Firmament, and why it always appears of that equally round Form: Alſo an Account of the Milky-Way.

THE ſky is not any thing real, but only the apparent boundary of our ſight. Space is every way infinitely extended, but our ſight is terminated all around us, at a ſmall but equal diſtance; and this is the only reaſon why the firmament appears of a perfectly ſpherical, concave figure; for the ſurface of a ſphere is every where equally diſtant from the center, and every man's eye is the center of his view; could he ſee farther one way than another the heavens would appear of an irregular form, and quite different from that beautiful hemiſphere, or azure canopy, which conſtantly repreſents itſelf to our view.

The Milky-way, Via Lactea, or Galaxy, is a white broad path or tract encompaſſing the whole heavens, and extending itſelf in the ſign of Capricorn, from the equinoctial to the tropic of Cancer, with a double path, and the reſt of it is a ſingle one.

Some of the ancients, as Ariſtotle, &c. imagined that this path conſiſted only of a certain exhalation hanging in the air, but by the teleſcope obſervations of this age, it has been diſcovered to conſiſt of an innumerable quantity of fixed ſtars different in ſituation and magnitude; from the confuſed mixture of whoſe light its white colour is ſuppoſed to be occaſioned.

This Milky-way begins at the equinoctial at Ophyus, or Sagittarius, and paſſeth thro' the conſtellations Aquila, Cygnus, Caſſiopeia, Perſus, Auriga, part of Orion, part of Scorpio, Sagittarius, Monoceros, Argo, Navis, and Ara. It paſſeth through the conſtellations of Caſſiopeia, Cygnus, Aquila, Perſeus, Andromeda, part of Ophiucus and Gemini, in the northern hemiſphere; and in the ſouthern, it takes in part of Scorpio, Sagittarius, Centaurus, the Argoanavis, and the Ara. Its greateſt declination north is about 65 degrees, and ſouth 69 degrees. It croſſeth the equinoctial from ſouth to north in 5 degrees of Capricorn; from north to ſouth in 5 degrees of Cancer. Its breadth, where broadeſt, is about 25 degrees near Aquila, but in other places it doth not exceed 10 degrees in breadth.—In the months of February and Auguſt you have a full view of it in the evenings.

Metrodorus, and ſome Pythagoreans, thought the ſun had once gone in this track inſtead of the ecliptic, and conſequently that its whiteneſs proceeded from the remains of his light,

As the Galaxy is compoſed of an infinite number of ſmall ſtars, ſo it hath uſually been the region in which new ſtars appear, as the ſtar in Caſſiopœia which was ſeen Anno Dom. 1572, that in the breaſt of the Swan, and another in the knee of Sagittarius and ſeveral others, which have appeared for a while, and then become inviſible again.

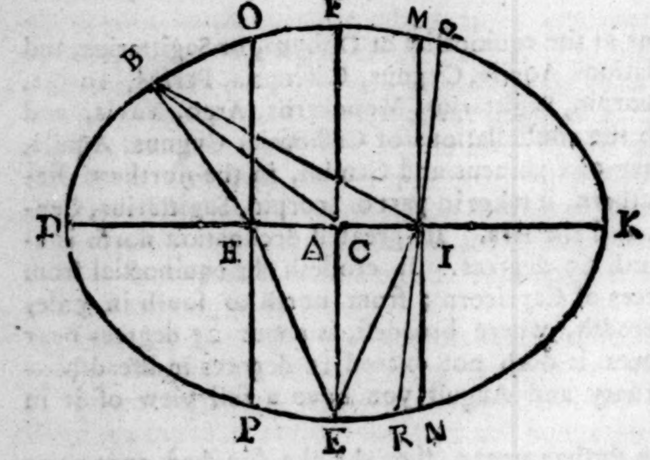
CHAP. IX.

An Account of the Sun's apparent Motion; how it makes a Difference of ſeveral Days between its Acceſs to and Receſs from the Equinoxes.

THE phænomena of the ſun's apparent motion round the earth, on which the theory of this vaſt body is eſtabliſhed, are by the aſtronomers obſerved to be theſe:

1. That the center of the ſun's body moves annually in the ſame plane of the ecliptic, and never deviates from the line ſo called; which apparent motion of the ſun doth in reality belong to the earth; which being at firſt put into ſuch a motion, and with ſuch a direction by the great Creator, will always continue to move after the ſame manner.

2. But the apparent motion of the ſun in the ecliptic is very unequal; for a little after the vernal, and a little before the autumnal equinox, he is in the mean between the extremes of his motion; but his motion is moſt ſwift a little after the winter ſolſtice, as 'tis always moſt ſlow a little after the ſummer one every year: All which ariſes from the earth's revolving not in a circle but in an ellipſis, in one of whoſe foci, or umbelici, the ſun is placed. And with this law alſo, that the areas deſcribed by lines drawn from the earth to the ſun, ſhall always be equal, in equal and proportional times.



In the figure annexed, let the ſun be in the point I, and let the curve F D E K be an ellipſis, or the annual orbit of the earth's center revolving round the ſun, and repreſented by B.

Let the point H be the other focus, and C the center of the ellipſis; K D is the greater axis, or linea apſidum, D the aphelion, and K the perihelion of the earth; F E is the leſſer axis, I C is the excentricity, or the diſtance between the center and the foci:—Let M N or O P be the latus rectum of the ellipſis; and let the right line A B biſſect the angle H B I.—Now ſince by lines drawn from its center to the ſun, the earth deſcribes areas always proportional to the times of its motion in the orbit, it will deſcribe equal areas in equal times. But ſeeing the line B I grows longer towards, and at the aphelion, and ſhorter at and about the perihelion, the earth muſt move ſlower in the former, and ſwifter in the latter caſe. And indeed the velocity of the earth's courſe in her orbit will always be in a reciprocal ratio of her diſtance from the ſun; ſo that if the diſtance between D and I be double to that between K and I, ſhe will move twice as faſt in the perihelion as in the aphelion. And from this figure it will be apparent, that the ſun's diameter will be greater when the earth is in her perihelion, which is a little after the winter ſolſtice†, and leſs when ſhe is in her aphelion, which is a little after the ſummer ſolſtice, as is found by obſervation. And this difference in his apparent diameter, ſhews alſo that the earth moves not in a circle, but in an ellipſis round the ſun.

Thoſe places in the ecliptic, in which theſe greateſt differences of the apparent motions and diameters of the ſun happen, in proceſs of time are changeable, and do move forward (or in conſequentia) equally: For tho' the aphelia and nodes of the planets are really at reſt and immoveable, yet, becauſe of the annual ceſſion of the equinoxes in antecedentia, they appear to be moved forward juſt the ſame quantity. If you ſuppoſe the ecliptic to be biſſected in the equinoctial points, the ſun appears to ſtay about 8 days longer in the northern than in the ſouthern half of that circle: For the elliptic orbit of the earth will be cut unequally by a line paſſing thro' the two equinoctial points. The perihelion not being far from the winter ſolſticial point, the equinoctial points will not be coincident with the longer axis, but almoſt with the latus rectum; for in the figure the line of the equinoxis Q R, is not much different from M N the latus rectum. But this inequality of the ſun's apparent motion is not now the ſame as it was in Ptolemy's time, and is continually changing, and in proceſs of time the equinoctial points will come to be in K and D, and then there will be no difference in the time of the ſun's ſtay in either ſegment of the ecliptic; but after this it will encreaſe again, and then again decreaſe as now, if the earth's annual motion be continued. And yet the ſpaces or times of the earth's entire revolution in her orbit are all equal to one another, and are what we call years, containing each 365 days, 5 hours, and 49 minutes nearly.

That the ſun's ſtay is about 8 days longer in the northern ſigns than in the ſouthern is obvious, by placing the months and days as follow:

Summer Months.		Winter Months.	
In March	10½	In September	7
April	30	October	31
May	31	November	30
June	30	December	31
July	31	January	31
Auguſt	31	February	28
September	23	March	20½
Summer	186½		178½
Winter	178½		
Difference	8 days		

Therefore 'tis a plain demonſtration that the earth does not keep an equal pace in all parts of its orbit.

N. B. Tho' the difference is here 8 days, yet in ſtrictneſs it is 7 days, 18 hours, 52 minutes.

CHAP.

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† Solſtice comes from *ſolis ſtatio*, the ſun's limit.——The ſun's diameter meaſured with a micrometer in a teleſcope, when the ſun was in the 8th degree of Capricornus, was found to be 1967 ſeconds, and when in 8 degrees of Cancer was only 1900, leſs by 70 ſeconds than before, which is near a 30th part of the whole.

CHAP. X.

The Calculation and Demonſtration of our Polar Star, that it was not the Pole at the Creation of the World, nor will be hereafter, but in Proceſs of Time will be to the South of the Zenith of London.

I Shall in this place, from Mr Leadbetter's aſtronomy, clear up this point, and make it plainly appear to any who are acquainted with the Golden Rule, that the ſtar of the 2d magnitude in the end of the tail of the Leſſer Bear was not the polar ſtar at the creation of the world.

"Firſt, then, you are to underſtand that this proceeds from two cauſes, the one by the receſſion of the equinox, which makes all the fixed ſtars ſeem to move in conſequentia 50 ſeconds a year; the other is their moving on the poles of the ecliptic, and therefore always keeping at the ſame diſtance from the ecliptic; but the declinations or diſtances from the equinoctial being always altering, hence it is that the fixed ſtars do not always keep the ſame places in the heavens, but are found ſometimes on this ſide, ſometimes on that, ſometimes to the north, at other times to the ſouth of your zenith: And this may ſeem a paradox to the unſkilful in aſtronomy; but I can aſſure you that there is not any one propoſition in Euclid more demonſtrable in itſelf than now the caſe before us."

I ſhall illuſtrate this, in giving the work of the preſent polar ſtar's neareſt approach to the pole, and alſo ſhewing when it will be ſouth of the zenith of London.

OPERATION.

1758 Long. of the pole of 2 ſ. 25° 11′ 21″ } lat. 66° 4′ 11″ N.
Subtract its long. from 3 00 00 00

Pole is now ſhort of ♋ 0 4 48 39
60

288
60

If 50″ : 1 year : : 17319
1

50) 17319 ($346\frac{19}{50}$ —
1758 add
Rem. 19

2104 ſum.

Latitude of the pole ſtar is 66° 4′ 11″ North.
Obliquity of the ecliptic add 23 29 00

Pole's declination — 89 33 11 North.

By the work it appears that 346 years hence, which will be in the year of Chriſt 2104, the pole ſtar's longitude will be in the firſt minute of Cancer, and then its declination will be 89° 33′ 11″ north, whoſe complement to 90° is 0° 26′ 49″. which is the neareſt approach of the polar ſtar to the pole itſelf that can poſſibly be.

As when the polar ſtar's neareſt approach to the pole is when its longitude is in the firſt minute of Cancer, ſo its greateſt diſtance from the pole will be when its longitude is in the firſt minute of Capricorn. The next thing therefore to be done is to find how long time it will be ere its longitude will be in the firſt minute of Capricorn, that is, in what ſpace of time it will, by its annual motion, move a ſemicircle, or from Cancer to Capricorn, which is found by this proportion:

$$\begin{array}{lllr} \text{If } 50'' & : & 1 \text{ year} \; : : & 180^\circ \\ & & & 60 \\ \hline & & & 10800 \\ & & & 60 \\ \hline \end{array}$$

$$50 \;)\; 648000 \;(\; 12960 \text{ years.}$$

Therefore in 12960 years the north polar ſtar (and alſo every fixed ſtar) will move half round the heavens, and in that time will alter their declination 46° 56′, equal to the diſtance of the two tropics; therefore if you ſubtract the diſtance of the two tropics from the declination of the polar ſtar when in Cancer, there will remain the declination of the polar ſtar when in Capricorn.

OPERATION.

Pole's declination when in Cancer	89°	33′	11″	North.
Diſtance of the two tropics ſubtract	46	58	00	
Pole's declination when in Capricorn	42	35	11	North.
Declination of the zenith of London	51	32	00	
Diſtance of the polar ſtar	8	56	49	to the ſouth

of the zenith or vertex of London.

Then to find when this will be: if to the year of Chriſt 2104, which is the time the polar ſtar will be in Cancer, you add 12960, the years it is moving from Cancer to Capricorn, the ſum 15064 is the year of Chriſt that the polar ſtar that we now obſerve will then be 8° 56′ 49″ to the ſouth of the zenith of London.—And if you would know what ſtar will be the polar ſtar in the year of Chriſt 15064, when our pole that now is will be to the ſouth of the zenith of London 8° 56′ 49″, it will be a ſtar of the third magnitude in the calf of the left leg of Hercules, whoſe longitude at preſent is ♐ 16° 27′ 50″, and latitude 69° 22′ north. And the ſtar that was the polar ſtar at the creation of the world, was a ſtar of the ſecond magnitude in the tail of Draco, whoſe preſent longitude is ♍ 4° 21′ 20″, and latitude 66° 36′ north.

For the better clearing up of this point, and for your own ſatisfaction, I ſhall acquaint you how you may prove what has been ſaid by the celeſtial globe: Thus; take in your compaſſes from any great circle of the globe (as from the equinoctial or ecliptic) the latitude of the preſent polar ſtar 66° 4′ 11″; carry this extent and ſet one foot in the very beginning of Capricorn, viz. in the point where the ſolſtitial colure, the ecliptic, and tropic meet or touch each other, and the other foot will fall in the ſame colure 8° 56′ 49″ ſhort or ſouth of the zenith of London, which is the place on the globe where the pole will be in the year of Chriſt 15064.

CHAP.

CHAP. XI.

Containing a Table, ſhewing the Times, at London, when the Planets Venus and Mercury will be viſible on the Sun's Face Diſk, together with their Diſtances from the Center of the Sun. Alſo ſome further Remarks on the Planets Saturn and Jupiter.

MERCURY.

Year of Chriſt.	Time of conj.	d.	h.	m.		Diſt. from ☉'s cent. ′	″
1786	May	3	6	57	M	12	43
1799	May	7	2	34	A	4	12
1782	Nov.	12	3	44	A	15	27
1789	Oct.	6	3	53	A	7	20

VENUS.

Year of Chriſt.	Time of conj.	d.	h.	m.		Diſt. from ☉'s cent. ′	″
1761	June	6	5	55	M	4	15
1996	June	9	2	13	A	13	36
2004	June	6	7	18	M	6	22
1874	Oct.	7	4	46	M	3	3
2109	Oct.	10	2	56	A	14	36
2117	Oct.	7	4	3	A	10	5

Note, A denotes afternoon, and M morning.

REMARKS on JUPITER and SATURN.

In the ſynopſis, I gave you an account that Jupiter had four ſatellites or moons, and I can aſſure you that theſe four moons muſt make a very pleaſing ſpectacle to the inhabitants of Jupiter, if there are any, for ſometimes they riſe all together; ſometimes they are all on the meridian, ranged one under another, and ſometimes they all appear in the horizon, and frequently undergo eclipſes; the obſervations whereof are of ſpecial uſe in determining the longitude.

From theſe four moons the inhabitants of Jupiter have four different kinds of months, and the number of moons in their year will not be leſs than 4500. Theſe jovial planets were firſt diſcovered by Galileo, by the help of the teleſcope which he firſt invented. We may learn from his diurnal motion that he cannot have above 5 hours day and 5 night, for he revolves round his axis in 9 hours, 56 minutes. But his year, which is his periodical revolution round the ſun, conſiſts of 4332 days, 12 hours, 20 minutes, 9 ſeconds, which is almoſt 12 of our years.

But beſides theſe curioſities in this planet, he has three appendages, called zones or belts, which Sir Iſaac Newton thinks are formed in his atmoſphere: In theſe are ſeveral maculæ or ſpots, from whoſe motion the motion of Jupiter, round its axis, is ſaid to have been firſt determined.

Saturn performs his periodical revolution in 10759 days, 6 hours, and 36 minutes; ſo that a Saturnian year is about $29\frac{1}{2}$ of our years.

He is accompanied with five ſatellites or moons, which muſt afford him great light in the night ſeaſon; beſides which, he is environed with a ring like the annular border of a pewter diſh, which, no where, touches his ſurface: Its plane is, at this time, nearly parallel to the plane of our earth's equator; the diameter of this ring is $2\frac{1}{4}$ of Saturn's diameter; and the diſtance of the ring, from the planet, is about the breadth of the ring itſelf. In one revolution of Saturn, this ring is twice very open, viz. when Saturn is in ♊ and ♐, and twice quite ſhut, viz. when ♄ is in ♍ and ♓.

This ring is undoubtedly of great ſervice to the inhabitants of Saturn, in reflecting both heat and light on the body of that planet, in that remote and conſequently cold and gloomy region.

Hence we may learn, that the all-wiſe creator, careſully provides every thing neceſſary to render every ſpecies of beings happy in their ſeveral ſtations.

C H A P. VIII.

Of the Quarters or Seaſons of the Year.

THERE are four quarters in the year: The firſt begins when the ſun apparently enters the equinoctial ſign Aries, making the days and nights equal all the world over, except under the poles, and continues while the ſun is running through ♈, ♉, ♊: This is called the ſpring quarter. The ſummer quarter begins about the 21ſt day of June, making the longeſt days to all the northern inhabitants. The third, is called the autumn, or harveſt quarter, and begins about the 23d of September, continues while the ſun is running through ♎, ♏, ♐, the days and nights are again equal. The fourth, and laſt, is called the winter quarter, making then the longeſt nights to all the inhabitants on this ſide the equator: This quarter continues all the time the ſun is paſſing through ♑, ♒, ♓.

PART III.

Containing a philoſophical Account of the Nature of Fluids; as Water, Air, Meteors, &c.

CHAP. I.

The Doctrine of Tides, with Rules to find the Time of full Sea at any propoſed Part continually.

TIDE ſignifies as well the ebbing as the flowing of the ſea; the former of which, ſeamen call the tide of ebb; the latter, the tide of flood.

This ſurprizing reciprocation of the ſea which ſufficiently puzzled the ableſt philoſophers, in all ages, till Sir Iſaac Newton's time, is now found to be only a particular law of nature, viz. that of mutual attraction; but here it is proper to premiſe, that the power of attraction decreaſes as the ſquares of the diſtances from the center of the attractive body increaſe. The flux and reflux of the ſea ariſes from the gravitation of the waters towards the ſun and moon, or the attractions of thoſe luminaries; for ſuppoſing the earth out of the ſphere of attraction of all other bodies, and void of motion, then if it be covered all over to a conſiderable depth with water, the ſurface thereof will form a perfect globe, being equally preſſed on all ſides, by the force of gravity, towards the center, would continue in a perfect ſtagnation, always at the ſame height, without ever ebbing or flowing. But ſince the ſun and moon have a like power of attracting towards their centers; and, that the earth, being within the orbs of their activities, it will plainly follow, that when ever the ſun or moon comes upon the meridian of any place, that the waters being thereby attracted, muſt of conſequence be ſo affected by its influence, as to gravitate leſs towards the earth's center than at the other times, and therefore muſt yield to the more powerful preſſure of the other parts of this incumbent fluid, and thereby occaſion the water to accumulate on that ſide of the earth which is next to it; but here it muſt be remarked, that the ocean alſo ſwells at the ſame time on the oppoſite meridian, viz. on the other ſide of the earth, the reaſon of which, will manifeſtly appear from the following conſideration. The attraction of the moon conſpires with that of the earth; but decreaſing as the ſquares of the diſtances increaſe, the joint force of attraction will every where decreaſe from the earth's centre to the oppoſite ſurface, where again the waters will be lighter, and therefore ſtand higheſt to preſerve the equilibrium; whence it appears, that, by this ſum, and difference of the luminaries and earth's attraction, there will neceſſarily enſue a portuberance, or ſwelling of the waters, which we call tides of flood, in two points, directly under the luminary on each ſide of the earth; and thus we account for this ſtupendous phænomenon.

Again, under two meridians, at a quadrant's diſtance from the two floods, as the waters are there moſt moſt attracted, ſo they will be heavieſt,

vieſt, and conſequently riſe to the leaſt height from the earth's ſurface, whence they are called tides of ebb, or the ebbing of the water.

This rightly underſtood, it follows plainly that the ſea, which otherwiſe ſhould be ſpherical, upon the action of the luminary, muſt form itſelf into a ſpheroidal or oval figure, whoſe longeſt diameter is where the luminary is vertical, and ſhorteſt where it is in the horizon; and, as the luminary ſhifts its poſition as it turns round the earth once a day, this oval of water ſhifts with it, occaſioning thereby the two floods and ebbs obſervable in each 25 hours.

But that the greateſt heighth of the water doth not fall juſt at the appulſe of the luminaries to the meridian, but follows the ſame by the ſpace of about three hours, is what I ſhall now undertake to explicate: That the thing is indeed ſo, appears from the obſervations of the tides, as well as in the Atlantic ocean, and the whole eaſtern tract of the Ethiopic, betwixt France and the Cape of Good Hope, as upon the coaſt of the Pacific, along Chili and Peru; in all which ſhores, the high water falls about three hours after the time aforeſaid, unleſs it be where the motion is retarded by its being propagated through ſhallows. Now, the reaſon is this: When the luminary is in the meridian, the attracting force is then certainly at the greateſt, but the effect of that force is not yet come to its height; for all impreſſed motion perſeveres uniformly until a contrary motion deſtroys, or at leaſt retards it. The flux of the ſea, or ocean rather, which, for the ſix morning hours, if we may ſo call them, when we ſpeak of the moon, is continually increaſed; and, by its conſpiring with the diurnal motion accelerated, ought, by reaſon of it greater celerity, to go forward ſtill further, and to accumulate the waters more and more, until the ſame force, by tending aftewards contrary to the diurnal motion, doth, by degrees retard the courſe of that motion which is going forwards; and, by and by, to make the ſame waters to proceed with ſo ſlow a motion, that a reflux of the ocean follows, which retardation of the motion ought to be moſt notable about the octants, or the third hour. Examples of ſuch like greateſt effects, as following ſome ſpace of time after their greateſt cauſes, we have yearly the greateſt heat of the ſummer, and cold of the winter, which falls not in the ſolſtices themſelves, but about the octants, if I may ſo ſpeak, about a month and a half after; and, in every ſummer day, in the greateſt heat of the day, which happens an hour or two after noon, rather than at noon itſelf; So, in the preſent caſe, whilſt after the greateſt force of all, and that riſing of the waters, which is thereby, forces next to the greateſt, and not yet turn'd to the contrary part, do ſtill operate; the forces which are leſs than the greateſt being ſuperadded to the motions, which were ſtirred up by the greateſt, and go forward by their own proper tendency, muſt needs obtain a greater effect than forces ſtill increaſing, ſuperadded to leſſer motions, could have: Then, it is to be noted alſo, that the attracting force itſelf, which lifts the water directly upwards, doth ſcarce ſenſibly fall ſhort of its greateſt quantity, for an hour or two after the appulſe of the luminary to the meridian, altho' the direction of the attraction which accelerates or retards the waters, be directly upwards in the meridian itſelf, and from thence is changed. The waters, therefore, will be moſt accumulated where the parts, which have juſt now paſſed the meridian, with the greateſt velocity, do fall upon other parts which had before been retarded at the quadrature; and ſo, by conſpiring with the endeavour of the other, do make the greateſt flood of all, which happens about the third hour. For,

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n this place, we intend, not ſo much the vulgar hours, as thoſe which are reckoned from the appulſe of the ſun or moon to the meridian of the place, as well below as above the horizon; and, by the hours of the lunar day, we underſtand 24 parts of that time, in which the moon, by its apparent diurnal motion, is revolved to the meridian of any place.

The effect of the ſun, upon the waters, is conſiderably leſs than that of the moon, tho' the gravity towards the ſun be vaſtly greater; for, it is not their actions, but the inequality of the actions of each which have any effect, as we have already proved. The ſun's diſtance is ſo great, that the diameter of the earth is a point compared to it; and, the difference between the actions on the neareſt and fartheſt parts becomes, on this account, vaſtly leſs than it would be if the ſun was as near as the moon, whoſe diſtance from us is about 30 diameters of the earth, as may be ſeen in the table of the ſynopſis of the different properties of planets. Thus the inequality of the action of the earth, on the parts of a drop of water is altogether inſenſible, becauſe the diameter of the drop is an inſenſible quantity compared with its diſtance from the center of the earth; (For, you are to apprehend, that all projectiles, as balls, ſtones, while they move in the air, attract the earth as well as they themſelves are attracted by it; but their effects upon it, being as inſenſible as their quantities of matter, are incomparable to the quantity of matter in it.)

However, the immenſe bulk of the ſun makes the effect ſtill ſenſible at ſo vaſt a diſtance; and, therefore, tho' the action of the moon has the greateſt ſhare in producing the tides, the action of the ſun adds ſenſibly to it when they conſpire together; as in the change and full of the moon, when they are nearly in the ſame line with the center of the earth, and therefore unite their forces; ſo that then the tides are greateſt, and are what we call ſpring-tides. The action of the ſun diminiſhes the effect of the moon's action in the quarters, becauſe the one raiſes the water in that caſe where the other depreſſes it; and therefore the tides are then leaſt, and theſe we call the neap tides: Though, to ſpeak accurately, the ſpring and neap tides muſt be ſome time after; becauſe, as in other caſes, ſo in this, the effect is not greateſt or leaſt when the immediate influence of the cauſe is greateſt or leaſt. The ſpring tide is the increaſing higher of a tide, after a dead or deep neap; this is about three days before the full or change of the moon, but the top or the higheſt of the ſpring tides is three days after the full or change, when the water runs higheſt with the flood and loweſt with the ebb, and the tides run more ſtrong and ſwift than in the neaps; and, as the higheſt of the ſpring tides are three days after the full or change, ſo the loweſt of the neap are four days before the full or change; and then the ſeamen ſay, it is deep neap, the moon being then in the middle of the ſecond and laſt quarter.

The tides which depend on the force of the ſun, and on the force of the moon, ſeverally, do not make a double tide but a ſingle one, which is eſtimated from the conjunction of their forces; for, like as any body whatever, which is impreſſed by a double force, cannot go forwards in two lines, but from the conjunction of the forces, will proceed in the diagonal of a parallelogram, in the ſame manner as if it had been acted upon by one ſingle force, according to the direction of the diagonal; ſo thoſe two motions, which the two luminaries do excite reſpectively, will not appear ſeverally, but will make one mixed motion.

The higheſt water does not always anſwer to the ſame ſituation of the moon, but happens ſometimes ſooner, and ſometimes later, than if the moon alone acted on the ſea.

This proceeds from the action of the ſun, which brings on high water ſooner, when the ſun alone would produce a tide earlier than the moon, as the ſun manifeſtly would in the firſt and third quarter, and retards the time of high water a little when the ſun alone would produce a tide later than the moon, as in the ſecond and laſt quarters.

The different diſtances of the moon from the earth produce likewiſe a ſenſible variation in the tides. When the moon approaches the earth, her action on every part increaſes, and the differences of that action, on which the tides depend, increaſe. For her action increaſes as the ſquares of the diſtances decreaſe; and tho' the differences of the diſtances themſelves be equal, yet there is a greater diſproportion betwixt the ſquares of the leſs than the ſquares of the greater quantities: As for example, 3 exceeds 2 as much as 2 exceeds 1, but the ſquare of 2 is quadruple the ſquare of 1, while the ſquare of 3 (viz. 9) is little more than double the ſquare of 2 (viz. 4).

Thus it appears, that by the moon's approach, her action on the neareſt parts encreaſes more quickly than her action on the remote parts, and the tides, therefore, increaſe in a higher proportion as the diſtances of the moon decreaſe.

Our author ſhews that the tides increaſe in proportion as the cubes of the diſtances decreaſe; ſo that the moon at half her preſent diſtance would produce a tide eight times greater.

The moon deſcribes an ellipſis round the earth, and in her neareſt diſtance produces a tide ſenſibly greater than at her greateſt diſtance from the earth: And hence it is that two great ſpring tides never ſucceed each other immediately; for, if the moon be at her neareſt diſtance from the earth at the change, ſhe muſt be at her greateſt diſtance at the full, having in the intervening time, finiſhed half a revolution, and therefore the ſpring tide then will be much leſs than the tide at the change was. And for the ſame reaſon, if a great ſpring tide happen at the time of the full moon, the tide at the enſuing change will be leſs.

The tides likewiſe ought likewiſe to be divers, according to the divers declination of the luminaries from the equator. For if the luminary was placed in either of the poles, it would draw the water conſtantly without intention or remiſſion of the action, and conſequently would make no reciprocation of the water. Now any place of the earth in deſcribing its parallel to the equator, would not meet, in its courſe, with any part of the water more elevated than another; ſo that there could be no tide in any place. Therefore the luminaries in departing from the equator towards either pole will, by degrees, loſe their effects; and therefore will raiſe leſſer tides after the ſolſticial ſyzygies than after the equinoctial. Hence the effect of the ſun or moon is greateſt when in the equator; for then the axis of the ſpheroidal figure, ariſing from their action, moves in the greateſt circle, and the water is put into the greateſt agitation; and hence it is, that the ſpring tides produced when the ſun and moon are both in the equator, are the greateſt of any, and the neap tides are the leaſt of any about that time. But after ſolſticial quadratures, the tides become greater than after the equinoctial, becauſe in the firſt caſe, the moon is in the equator, and in the latter caſe, the moon is in one of the tropics, and the tide depends more on the action of the moon than that of the ſun, and is therefore greateſt when the moon's action is greateſt.

However, becauſe the ſun is nearer the earth in winter than in ſummer, it comes to paſs, that the greateſt ſpring tides are often after the autumnal, and before the vernal equinox; which yet does not happen every year, becauſe ſome variation may ariſe from the ſituation of the moon's orbit, and the diſtance of the ſyzygy from the equinox.

When the moon declines from the equator towards either pole, one of the greateſt elevations of water follows the moon, and deſcribes nearly the parallel on the earth's ſurface, which is under that which the moon, becauſe of the diurnal motion, ſeems to deſcribe; and the oppoſite greateſt elevation, being antipodes to that, muſt deſcribe a parallel as far on the other ſide of the equator: So that while the one moves on the north ſide of the equator, the other moves on the ſouth ſide of it at the ſame diſtance. Now the greateſt elevation which moves on the ſame ſide of the equator with any place, will come nearer to it than the oppoſite elevation, which moves in a parallel on the other ſide of the equator; therefore if a place is on the ſame ſide of the equator with the moon, the day-tide, or that which is produced while the moon is above the horizon of the place, will exceed the night tide, or that which is produced while the moon is under the horizon of that place. It is the contrary if the moon is on one ſide of the equator and the place on the other, for then the elevation which is oppoſite to the moon moves on the ſame ſide of the equator with the place, and therefore will come nearer to it than the other elevation. This difference will be greateſt when the ſun and moon both deſcribe the tropics; becauſe the two elevations in that caſe deſcribe the oppoſite tropics, which are the fartheſt from each other of any two parallel circles they can deſcribe. Thus it is found by obſervation that the evening tides in ſummer exceed the morning tides, and the morning tides in winter exceed the evening tides. The difference is found at Briſtol to amount to 15 inches, at Plymouth to one foot, as appears from the obſervations of Mr Sturmy and Mr Colepreſs. It would be ſtill greater, but that a fluid always retains an impreſſed motion for ſome time, ſo that the preceding tides always affect thoſe that follow them.

The motions deſcribed hitherto are ſomething changed by that force of the reciprocation of the waters, wherewith the tide, even though the actions of the luminaries ſhould ceaſe, might endure for ſome time. This conſervation of the motion once impreſſed doth diminiſh the difference of the alternate tides, and makes the tides next after the ſyzygies greater, and diminiſhes thoſe next after the quadratures. For from hence it comes to paſs that the alternate tides at Plymouth and Briſtol do not differ much more than by the height of 12 or 15 inches; and that the greateſt tides of all in the ſame ports, are not thoſe which are next after the ſyzygies or conjunctions, but the third tides after them; which agrees exactly with what was ſaid before. For all thoſe motions are retarded in their paſſing through ſhallows; ſo that the greateſt tides of all in ſome ſtreights, and the mouths of ſome rivers, are the fourth, or even the fifth after the ſyzygies.

The phænomena of particular places agree with theſe general obſervations, if the ſituation and extent of the ſeas and ſhores in which they are ſituated are conſidered. It has been always known that the tides follow the motion of the moon, riſing twice in one revolution of the moon to the meridian of any place, which exceeds a ſolar day by above three quarters of an hour, becauſe the proper motion of the moon retards ſo much her appulſe to the meridian of any place.

All the effects of the ſun's action, ſometimes promoting, ſometimes abating the effects of the action of the moon, as before-mentioned; are alſo conformable to perpetual obſervation: And the tides in places that lie on a deep and open ocean, where the water can eaſily follow the influence of the ſun and moon, are agreeable to this theory.

That tides may have their full motion, the ocean in which they are produced ought to be extended from eaſt to weſt 90°, or a quarter of the circumference of the earth at leaſt; becauſe the places where the moon raiſes moſt, and moſt depreſſes the water, are at that diſtance from each other. Hence it appears, that it is only in the great oceans that ſuch tides can be produced; and why in the larger Pacific ocean they exceed thoſe in the Atlantic ocean. Hence alſo it is obvious why the tides are not ſo great in the torrid zone, between Africa and America, where the ocean is narrower, as in the temperate zones on either ſide; and from this alſo we may underſtand why tides are ſo ſmall in iſlands that are very far diſtant from the ſhores. It is manifeſt that, in the Atlantic ocean, the water cannot riſe on one ſhore but by deſcending on the other, ſo that at the intermediate diſtant iſlands it muſt continue at about a mean height betwixt its elevation on the one and on the other ſhore.

As the tides paſs over ſhoals, and run through ſtraits and bays of the ſea, their motion becomes more various, and their height depends upon a great many circumſtances.

The tide that is produced on the weſtern coaſts of Europe, in the Atlantic, correſponds to the ſituation of the moon we deſcribed above. Thus it is high water on the coaſts of Spain, Portugal, and the weſt of Ireland, about the third hour after the moon has paſſed the meridian: From thence it flows into the adjacent channels as it finds the eaſieſt paſſage. One current from it, for example, runs up by the ſouth of England, another comes in by the north of Scotland; they take a conſiderable time to move all this way; and it is high water ſooner in places to which they firſt come; and it begins to fall at thoſe places, while they are going on to others that are farther in their courſe. As they return, they are not able to raiſe the tide, becauſe the water runs faſter off than it returns, till, by a new tide propagated from the open ocean, the return of the current is ſtopped, and the water begins to riſe again.

The tide takes twelve hours to come from the ocean to London bridge, ſo that, when it is high water there, a new tide is already come to its height in the ocean; and in ſome intermediate place, it muſt be low water at the ſame time. In channels therefore, and narrow ſeas, the progreſs of the tides may be, in ſome reſpects, compared to the motion of the waves of the ſea.

Our author alſo obſerves, that when the tide runs over ſhoals, and flows upon flat ſhores, the water is raiſed to a greater height than in the open and deep oceans that have ſteep banks; becauſe the force of its motion cannot be broke upon theſe level ſhores, till the water riſes to a greater height.

In ſome ports as hath been very lately obſerved, where the water paſſing through ſhallow places is forced to flow in and out with great rapidity, to fill and empty by turns narrow bays, the tides are greater than uſual; as at Plymouth and Chepſtow bridge, in England; the hills of St Michael, and the city of Avranches, in Normandy; Cambaia and Pegu, in the Eaſt-Indies. In theſe places, the ſea coming and going back with a great velocity, ſometimes overflows the ſhores, and then leaves them dry for many miles. Nor can the force of flowing in and reflowing be ſtopped, until the water be elevated or depreſſed 30, 40, 50, or ſometimes 60 feet. And the thing is the ſame, in ſome meaſure, in long, ſhallow, and narrow ſtreights, as the Magellanic, and that wherewith England is encompaſſed. But in ſhores which have a ſteep deſcent towards a deep and open ſea, where the water may be raiſed and ſettle freely without any acceſſional force of flowing in and returning; the tide, if we would determine the general mean quantity, is to be reckoned to riſe to the height of about 12 feet, that is, if we meaſure from the low to the high water mark. It may come to paſs alſo through the length of the way, or the various winding of the ſame, or by means of obſtacles which are in the way, that the tide may be diminiſhed and almoſt ſtopped. From whence it comes, that where there are a great number of iſlands, as the Muluccoes, the Philippines, in the Mexican bay, the Antilles, there is almoſt no flux, or far leſs than in the wide and open ocean.

If a place communicates with two oceans (or two different ways with the ſame ocean, one of which is a readier and eaſier paſſage) two tides may arrive at that place in different times, which interfering with each other, may produce a great variety of phænomena.

An extraordinary inſtance of this kind is that which Dr Halley ſpeaks of from the obſervations of mariners, as being in a port called Batſha, in the kingdom of Tunquin, in the Eaſt-Indies, of northern latitude 20° 50′. The day on which the moon paſſes the equator, the water ſtagnates there without any motion: As the moon removes from the equator, the water begins to riſe and fall once a day; and it is high water at the ſetting of the moon, and low water at her riſing. This daily tide increaſes for about ſeven or eight days, and then decreaſes for as many days by the ſame degrees till this motion ceaſes, when the moon has returned to the equator. When ſhe has paſſed the equator, and declines towards the ſouth pole, the water riſes and falls again as before; but it is high water now at the riſing, and low water at the ſetting of the moon.

Our author, to account for this extraordinary tide, conſiders that there are two inlets to this port of Batſha, one from the Chineſe ocean betwixt the continent and the Manillas, the other from the Indian ocean between the continent and the iſland of Borneo. This leads him to propoſe, as a ſolution of the phænomenon, that a tide may arrive at Batſha through one of theſe inlets, at the third hour of the moon, and another through the other inlet ſix hours after, at the ninth hour of the moon. For while the tides are equal, the one flowing in as the other ebbs out, the water muſt ſtagnate. Now they are equal when the moon is in the equator, but as ſoon as the moon begins to decline on the ſame ſide of the equator with Batſha, we have ſhewed that the diurnal tide muſt exceed the nocturnal, ſo that two greater and two leſſer tides muſt arrive at Batſha by turns. The difference of theſe will produce an agitation of the water, which will riſe to its greateſt height at the mean time betwixt the two leaſt tides; ſo that it will be high water about the ſixth hour at the ſetting of the moon, and low water at her riſing.

When the moon has got to the other ſide of the equator, the nocturnal tide will exceed the diurnal, and therefore the high water will be at the riſing, and low water at the ſetting of the moon.

The ſame principles will ſerve to account for other extraordinary tides, which, we are told, are obſerved in places whoſe ſituation expoſes them to ſuch irregularities.

Our author does not content himſelf with theſe general obſervations, but calculates the effect of the ſun and moon upon the tides, from their attractive powers. The augmentation of the gravity of the lateral parts of the earth, (that is, thoſe which are at the diſtance of a quarter of a circle from the point which is directly below the luminary) produced by the action of the ſun, is a ſimilar effect to an augmentation, eſtimated by him before, that is made to the the gravity of the moon towards the earth by the ſame action when the moon is in the quarters, only the addition made to the gravity of the lateral parts is about $60\frac{1}{2}$ times leſs, becauſe their diſtance from the earth's center is ſo many times leſs than the diſtance of the moon from it.

The gravity of thoſe parts of the earth that are directly beneath the ſun, and of thoſe oppoſite to it, is diminiſhed by a double quantity of what is added to the lateral parts; and as the diminution of the gravity of the one, and the augmentation of the gravity of the other, conſpire together in raiſing the water under the ſun, and the parts oppoſite to it, above its height in the lateral parts: The whole force that produces this effect is to be conſidered as triple of what is added to the gravity of the lateral parts; and is thence found to be to the gravity of the particles as 1 to 12868200, and to the centrifugal force at the equator, as 1 to 44527. The elevation of the waters by this force, is conſidered by our author as an effect ſimilar to the elevation of the equatorial parts above the polar parts of the earth, ariſing from the centrifugal force at the equator; and, being 44527 times leſs, is found to be 1 foot and $11\frac{1}{30}$ inches, Paris meaſure; this is the elevation ariſing from the action of the ſun upon the water.

In order to find the force of the moon upon the water, he compares the ſpring tides at the mouth of the river Avon, below Briſtol (which are the effect of the ſum of the forces of the ſun and moon when their actions almoſt conſpire together) with the neap tides there, (which are the effect of difference of theſe forces when they act almoſt againſt one another) and finds their proportion to be that of 9 to 5; from which, after ſeveral neceſſary corrections, he concludes, that the force of the moon is to the ſun, in raiſing the waters of the ocean, as 4,4815 to 1, or in round numbers, almoſt five fold; ſo that the force of the moon is able of itſelf to produce an elevation of 8 feet and $7\frac{5}{12}$ inches, and the ſun and moon together may produce an elevation of about $10\frac{1}{2}$ feet, in their mean diſtances from the earth, and an elevation of about 12 feet when the moon is neareſt the earth.

The height to which the water is found to riſe, upon the coaſts of the open and deep ocean, is agreeable enough to this computation.

It is from this laſt calculation that he is able to make an eſtimate of the denſity and quantity of matter in the moon. Her influence on the tides is the only effect of the moon's attracting power which we have acceſs to meaſure, and it enables us to eſtimate her denſity compared with that of the ſun, which we find it exceeds in the proportion of 4891 to 1000; and ſince the denſity of the earth is to that of the ſun, as 4000 to 1000, it follows, that the moon muſt be more denſe than the earth in the proportion of 4891 to 4000, or of 11 to 9 nearly. The proportion of the diameter of the earth to that of the moon is known, from aſtronomical obſervations, to be that of 365 to 100, and from theſe two proportions it eaſily follows, that the quantity of matter in the moon is to the matter in the earth, as 1 to 39,788 ; and the center of gravity of the earth and moon muſt be thereſore almoſt 40 times nearer to the earth than to the moon ; and the ſituation of their center of gravity being known, the motions of their ſyſtems may be determined with great preciſeneſs.

Our author enquires into the figure of the moon ; and, becauſe the earth contains near 40 times more matter than the moon, the elevation produced by the action of the earth in the parts of the moon that are neareſt to it, and in the parts oppoſite to theſe, would be near 40 times greater than that which the moon produces in our ſeas, if this elevation was not to be diminiſhed in proportion as the ſemidiameter of the moon is leſs than the ſemidiameter of the earth, that is, in the proportion of 100 to 365. By compounding theſe proportions he finds, that the diameter of the moon that paſſes through the center of the earth, muſt exceed thoſe that are perpendicular to it by about 186 feet. He thinks the ſolid parts of the moon muſt have been formed into ſuch a ſpheroidal figure, having its longeſt diameter directed towards the earth ; and this may be the reaſon why the moon always turns the ſame ſide towards the earth. If there were great ſeas in the moon, and if ſhe revolved on her axis ſo as to turn different ſides towards the earth, there would have been very great tides produced in them, ſuch as would exceed our tides ten times ; but by her keeping one ſide always towards the earth, there are no tides produced in her ſeas, but what proceed from the differences of their diſtances from the earth, and from the moon's liberations ; for the action of the ſun can have very little effect upon them.

Tides are denominated by the titles of *windward* and *leeward:* When the tide or flow of water runs againſt the wind, it is called a *windward* tide, in which caſe the ſea breaks moſt, and runs higheſt. A *leeward* tide is when the wind and tide go both the ſame way.

It is ſaid to flow tide and half tide, when the tide runs three hours (which is 4 points of the compaſs) in the offing, longer than it doth by the ſhore.

N. B. By longer is not meant more hours, for it always ebbs and flows ſix hours, but that if it be high water aſhore at twelve o'clock, it will not be ſo in the offing till three, which is the bound time for the running of a half tide. If it ebbs and flows more it is ſaid to run half tide and half quarter, that is five points.

I ſhall now proceed to give rules for finding the time of full ſea at any propoſed place continually.

It is evident from the preceding part of this diſcourſe, that it chiefly depends on the moon's ſouthing ; now I have given you a rule to find the moon's ſouthing in part the firſt, page 37, to which I refer you, and ſhall only inſert the following table in this place, which is deduced from it.

The

The TABLE.

Moon's ag.	Time. h.	Time. m.
1—16	0	48
2—17	1	36
3—18	2	24
4—19	3	12
5—20	4	0
6—21	4	48
7—22	5	36
8—23	6	24
9—24	7	12
10—25	8	0
11—26	8	48
12—27	9	36
13—28	10	24
14—29	11	12
15—30	12	0

The 1ſt and 2d column ſhews the moon's age, the 3d her ſouthing.——Examp. The moon being 9 days old, and her ſouthing required: In the 1ſt column, under moon's age, ſtands 9, and over-againſt it in the laſt column is 7 hours and 12 minutes, the time of ſouthing required.

Note, The ſame ſouthing ſerves for 24 days old as ſerves for 9 days, as the table ſhews; only obſerve, after the moon is turned 15 days old, ſhe ſouths in the morning, which before ſouthed in the evening.

A Tide Table for the Sea Coaſts of Great Britain, Ireland, Norway, Holland, Flanders, France, Biſcay, &c. ſhewing what Moon makes full Sea, upon the Full and Change Days, at the Places following.

	h.	m.	☽ *Bear.*
Beachy, Condado, Dunkirk, Dover, Embden, Eyder, Flander's Coaſt, Gibraltar Road, Graveling, Hever, Horn, Hampton key, Jutland iſles, Kentiſh knock, Leith, Newport half tide, Portſmouth half tide, Queenborough, Shoe, Sleeve, Southampton, before Ureck	12	0	N. & S.
Aberdeen, Thwart of Beachy in the offing, Fluſhing Maze, within Malden, Nore weſt end, Rocheſter, Rebden, in the chamber of Rye, Tervere within, Winchelſea	12	45	N. by E. and S. by W.
Army Blackneſs, Belle-Iſle, Berwick, Calice without, Campher, Corpus Chriſti point, Finmark coaſt, Goore, Guernſey, Graveſend, Holy Iſland, before the Maze, Rumney, Ramkins, Tinmouth, Tervere without, Zealand coaſt	1	30	N.N.E. and S.S.W.
St Andrew's, Berwick, without Bluet, Dundee, Denby, Downs in the Road, Fountnay without, Liſbon, St Lucas, St Mark	2	15	N.E. by N. & S. W by S
Amſterdam, Armentieres, Bertagne ſouth coaſt, Bourdeaux river, Biſcay coaſt, Bockneſs, Dort, without the	3	0	N.E. & S. W.

banks

	h,	m.	☽ Bear.
banks of Flanders, Galica, Gaſcoign, Groyn, Ireland weſt coaſt, Kelliers, London, before the river of Nantz, Orkneſs at the Pens, Porthus and Poictu, Rotterdam, in Robin Hood's bay, and from the Race to the Polehead, upon the coaſt of Spain and Shetland, before Tees and Tinmouth, before the bay of Tinmouth, Ouſe, Whitby, in the Zeric ſea — — —	3	0	N. E. and S. W.
Breſt, Baſs without, Bridlington, Bourdeaux river within, Brovage without, Huntcliffoot, St Matthew's Point, Portugal coaſt, Rouen, Rochelle without, Sicily, Scarborough ſound, Staples, between Uſhant and the Main — —	3	45	N.E. by E. and S. W, by W.
Albarwark, Blatimore, Bloy, Bridlington, Breeſound, Cork, Calice, Cape Clear, and in the Creek, Dunbar, Dungervan, Edinburgh, Egmon, Firth, Flamborough, Humber without, Kingſail, Leigh, Lawrenceſs, Mount's Bay, Mouſehole, Severn, Seven Iſles, Wales ſea, Younghall — — —	4	30	E.N.E. and W.S W
Arbroth, Clady, Carmarthen bay, Form, Foy, Falmouth, Humber, Ireland ſouth coaſt, Lynn without, Londy, Milford, Moonleſs, St Maloes, Newcaſtle, Plymouth, before St Paul's, Ramſey, Stockton, Wales	5	15	E. by N. and W. by S
Antwerp, Abermorich, Archangel, Breman, Blackney, Channel before, Bourdeaux, Concalo, Dartmouth, St David's Head, Lynn half tide, Londonderry, Londey, St Paul's, Salcomb, Scilly without, Uſhant, Waterford	6	0	E. & W
Briſtol key, Foulneſs, between Foy and Falmouth, in the Channel, Lynn, St Nicholas in Ruſſia, Podeſemſky in Ruſſia, Start, Sedmouth, Weymouth key —	6	45	E. by S. and W by N
Bridgwater, Exwater, Emes entrance, Frizeland, the Fly, Florida, Kilduyn, Land's End, Lizard, Milford haven, between Mouſehole and Falmouth, thwart of Plymouth, off the Strat in the Channel, in the road of the Texel, Neſs by Wieringhen, Winterton	7	30	E. S.E. and W N W
Caſkets without, Fly without, St Helen's, Hague, Lambay, Magnes ſound, Mackneſs caſtle, Needles, Portland, Peter Port, Iſle of Wight, Waxford, Yarmouth Road	8	15	S. E by E & N W by W.
Between Caſkets and Guernſey, Seven Clifts, Catneſs, Dunbar, Homehead, Herlem, Havre-de-Grace, Iſle of Man, Kildive, Orkney, Portland Race, Seyn within, before Shelberg, Wieringhen flats —	9	0	S. E. & N. W.
Alborough, Caſkets, Chamberneſs, Dunnoſe, Dunge-	9	45	

	h. m.	
neſs, thwart of Guernſey, Leyſtaff, Leynow, Orfordneſs, Shoreham, Torgen — —	9 45	S E.byS & N.W by N.
Arklow, Bullendeep, Cows, Foſs of Caen, Calice Road, Chamberneſs Road, Cheſter, Dover, Dieppe, Downs aſhore, Dublin bar, Drogheda, Dundalk firth, South Foreland, St Hellen's, Harwich, Holyhead, Leyſtaff Road, Long Sand head, Normandy coaſt, Picardy coaſt, Orfordneſs without, Seynhead, St Vallery, Whitehaven, Yarmouth haven — —	10 30	S. S. E. and N.N W
Galſhot, Carlingford, Carrickfergus firth, Fair Iſle roads, North Foreland, Gorend, Goree, Liverpool, Margret road, Marlinford, Naze, Orfordneſs within the ſands, Rye, Rhodes, Strangford —	11 15	S. by E. and N by W

Note, That ſpring tides, contrary winds, or land floods, may cauſe the tides to vary ſooner or later, about an hour's ſpace.

Having the time of the full ſea of thoſe ſeveral ports in the table given, on the full and change days of the moon, you may with very little trouble find the time of full ſea in any of theſe ports at other times, viz. by adding the time of the moon's ſouthing to the point of the compaſs making full ſea, on the full and change day, for the place propoſed; that ſum is the time of full ſea or high water.

EXAMPLE.

Suppoſe the moon being 9 days old, the time of full ſea in the Downs is required.

It is found to flow in the Downs S. S. E. and N. N. W. that is, when it is full ſea in the Downs, the moon will be, as it is vulgarly ſaid, upon the ſouth, ſouth-eaſt, and north, north-weſt points of the compaſs, which, as the compaſs* and table ſhew, is 10 hours and 30 minutes; to which adding the moon's ſouthing at 9 days old, viz. 7 hours and 12 minutes, it makes 17 hours and 42 minutes, or 5 hours and 42 minutes, rejecting 12 hours in the morning.

But to be more exact, uſe the following table and directions.

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* The hours and minutes are graduated on the verge or margin of the compaſs.

The TABLE.

Moon's age	Time. h. m.
1—16	0—43
2—17	1—20
3—18	1—52
4—19	2—22
5—20	2—52
6—21	3—26
7—22	4—07
8—23	4—55
9—24	5—50
10—25	6—53
11—26	7—59
12—27	9—04
13—28	10—08
14—29	11—05
15—30	00—00

Having found the time of full ſea upon the full and change days by the preceding table for that purpoſe, enter this table with the moon's age, againſt which, in the laſt column, are the hours and minutes to be added for the time of full ſea required.

EXAMPLE.

Suppoſe as before, the moon being nine days old, and the time of full ſea in the Downs is required, a N. N. W. and S. S. E. moon makes full ſea upon the full and change days, which is 10 hours and 30 minutes, which being found, enter this table with the moon's age, 9 days, againſt which ſtands 5 hours and 50 minutes, which added to 10 hours, 30 minutes, makes 16 hours, 20 minutes, or 4 hours, 20 minutes (rejecting 12 hours) in the morning.

EXPLANATION of the TYPE in the following Page.

At London on the day of the new and full moon, it is high water at three of the clock, that is, when the moon is 3 hours paſt the meridian: And ſo by the common rule* (p. 37) the moon being about 4 days old, it will be ſouth about three of the clock. But now by this rule, if you count this time of the moon's coming to the ſouth in the circumference, the perpendicular line which comes from 3 to 9 cuts the diameter in the half at 45 minutes; which ſhews, that ſo much is to be abated from the time of high water to the new and full moon; ſo that it is high water 45 minutes before 6 of the clock, that is at 5 hours, 15 minutes, and not at 6 o'clock according to the common rules.

If the time of full ſea be required for any port which is not inſerted in the table, then for finding the tides obſerve the following directions. Firſt, divide a circle into 12 equal parts, or hours, according to the moon's motion or diſtance from the ſun, from the new to the full.—

Se-

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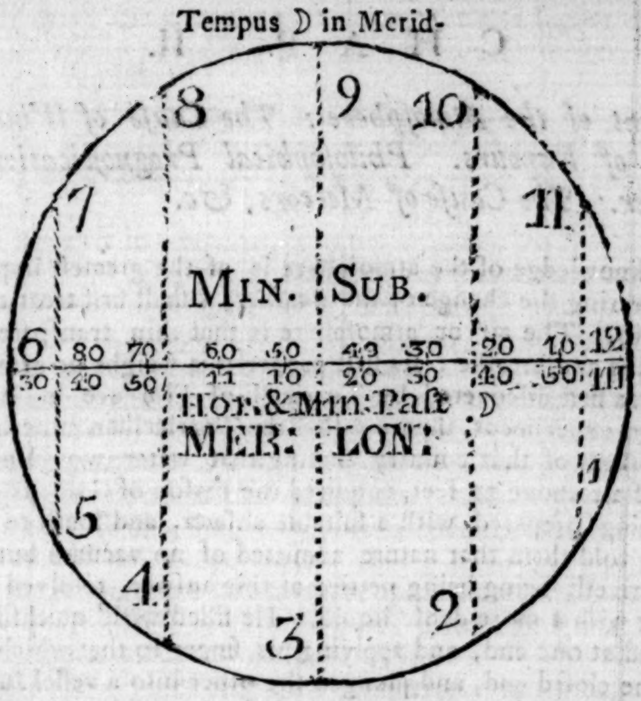
* The ſaid common rule only divides 24 hours equally among 30 days, without regard to either the inequality of the moon's motion or her latitude, which renders it liable to ſome ſmall errors.



Secondly, let the diameter of the circle be divided into 90 parts or minutes, that is, according to the time of the difference of tides between the new and fullmoon, and the quarters, which is $1\frac{1}{2}$ hour.—Thirdly, make perpendicular lines croſs the diameter of the circle from hour to hour.—Fourthly, reckon the time of the moon's coming to the ſouth in the circumference of the circle, and obſerve the perpendicular line that falls from that point upon the diameter, and the proportional minutes cut thereby will ſhew how many hours or minutes are to be ſubtracted from the time of high tides at the new and full moon, that ſo you may have the true time of the tides that preſent day.

The like you may do for any other port or place, knowing the time of high water at new and full moon under the diameter, as it is done for London in this example, where it is high tide at three of the clock; ſo that when the moon is ſouth at three of the clock, the perpendicular cuts the diameter at 2 hours, 15 minutes, which added to the time of the ſouthing, gives 5 hours, 15 minutes; and ſo when the moon is ſouth at nine of the clock, by adding 2 hours, 15 minutes, you have the time of high water, which is 11 hours, 15 minutes.

And thus you may eaſily make a table, which by the ſouthing of the moon, ſhall readily tell you the time of high water at any time of the moon.

Note, If the difference be not ſo much between the neap tides and the ſpring tides in other places as it is in this our example, the diameter muſt be divided into fewer parts.

CHAP.

CHAP. II.

An Account of the Atmoſphere: The Cauſe of Winds: The Aſcent of Vapours. Philoſophical Prognoſtications of the Weather. The Cauſe of Meteors, &c.

AS the knowledge of the atmoſphere is of the greateſt importance in diſcovering the change of the weather, I ſhall firſt treat of it as previous thereto. The air or atmoſphere is that thin tranſparent fluid in which we live and breathe: Its firſt property is weight or gravity: This property was firſt diſcovered by Torricelli of Florence in Italy, A. D. 1643, by an experiment, thence called the Torricellian experiment. The fountain-makers of that country finding that water would not riſe in a pipe void of air above 32 feet, enquired the reaſon of Galileus, his maſter, who not being prepared with a ſuitable anſwer, and loath to expoſe his ignorance, told them that nature admitted of no vacuum but above 32 feet. Torricelli being being nettled at this anſwer, reſolved on a new experiment with a more denſe liquid. He filled with quickſilver a tube cloſe ſtopped at one end, and applying his finger to that which was open, he raiſed the cloſed end, and plunged the other into a veſſel full of quickſilver; then removing his finger, without letting the open end touch the bottom of the veſſel, he ſaw the quickſilver deſcend in the tube, and leave a vacuum at top, and remain ſuſpended at the height of 27 inches.

He thence concluded this abhorrence of a vacuum was only a chimerical idea. This diverſity of elevations in two very different liquids ſeemed to him to proceed from the difference of their weight; he fancied that he had a crude notion that a column of air correſponding to the orifice of the two tubes, might hinder the liquids from falling, and ſuſtain them at unequal heights; becauſe the 27 inches of quickſilver being probably of the ſame weight with 32 feet of water, which is a more ſubtile matter, the column of air might be equivalent to either body. This conjecture, and repeated experiments, confirming it, took wind. M. Paſchal thought that in reaſon the column of air ought to weigh leſs at the top of a hill than at the bottom, becauſe the column is ſhorter at the ſummit than at the ſoot; and nothing ſeemed to him more ſatisfactory than the proof made by his care upon the Pui-de-dome, near Clermont, in France, it being ſound according to his expectation that the quickſilver, which at the foot of the hill was ſuſtained at 30 inches, at the top it deſcended to 27. Some virtuoſi who had let ſtand one of theſe tubes, ſoon perceived that the mercury which was kept ſuſpended was not always at the ſame height, that it roſe in dry weather, fell againſt rain, and had ſudden agitations at the approach of ſtorms. They reduced all theſe obſervations to a rule, and by placing a graduated paper or ſcale, with an index adapted to Nonius's diviſions, they can now diſcover even the minuteſt alterations of the atmoſphere, and thus become able to prognoſticate the change of the weather; and the inſtrument, which is daily improving, is called the barometer, or weather-glaſs.

Note, Inſtead of a ſmall veſſel which was ſeparate from the tube, they now fix to it a ciſtern filled with mercury. This glaſs ciſtern being open at the upper end to receive the preſſure of the air, is made ſometimes 60 or 80 times of a greater diameter than the tube, the preſſure of the air muſt conſequently drive the mercury nigh 60 or 80 times higher in the tube than it would raiſe in the ciſtern ; wherefore the alterations in the tube become very perceptible.

The ſecond property of the air is elaſticity*, that is, a certain ſpringing force by which it always endeavours to expand, ſwell, or encreaſe itſelf in bulk. Many experiments may be brought to prove this wonderful property of air.

Tie up a little air in a bladder, and put it under the receiver of an air pump, and when the air is pumped out, that in the bladder will ſwell ſo as to fill it : And even thin ſquare phials, well ſtopped, will break to pieces when once the air is pumped out of the receiver. I could produce ſeveral inſtances more if this property was diſputed.

Having demonſtrated theſe two properties of the air, I ſhall proceed to give a more particular account of the atmoſphere. It is requiſite to obſerve that the atmoſphere is a perfect chaos of different effluvia, conſiſting of almoſt all kinds of corpuſcles confuſedly jumbled together, and conſtituting one maſs : Water, fire, volatile ſalts and oils, &c. are there blended together in different proportions. Hence it is no wonder that the gravity of the atmoſphere ſhould vary, according as the more light or more ponderous of theſe conſtituent parts prevail in it ; and in fact is found to ſuſtain a pillar of mercury 31 inches high in the barometer, when at other times it will only raiſe the mercury to the height of 28 inches.

Taking therefore $29\frac{1}{2}$ inches for the mean altitude of the quickſilver, a column of it whoſe baſe is one ſquare inch weighs about 15 pounds, which is equal to the preſſure of the air upon every ſquare inch : Hence, ſuppoſing the ſurface of a man's body to be $14\frac{1}{2}$ ſquare feet, the air ſuſtained by him will be 31320 lb. or nearly 14 tons, at a medium ; whereas when the air is lighteſt it will be only $13\frac{1}{5}$ tons, and when heavieſt $14\frac{3}{10}$ tons, the difference of which is $1\frac{1}{10}$ tons, equal to 2464 lb. wherewith we are more compreſſed at one time than another.

This grand difference of preſſure muſt greatly affect us in regard to the animal functions, and conſequently in reſpect to health. If a perſon, for inſtance, be aſthmatical, he will find his diſorder increaſe with the levity of the air. Again, the reaſon why we think the air is lighteſt in fine weather when it is really heavieſt, is becauſe the greater preſſure conſtringes the fibres and nerves, and thereby makes us more vigorous than ordinary ; whereas on the contrary, when this preſſure is leſſened by near 2500 lb. the fibres are relaxed, and a gloomy inactiuity and heavineſs enſues.

Tho' this relation at firſt may appear ſtrange, yet nothing is more evident, when it is conſidered that our bodies as well as others, are filled with air throughout, and the ſpring of this internal air is a force juſt equal to the preſſure of the air without ; and when two forces, equal to each other, act in contrary directions, they entirely deſtroy each others effects ; and any body, being preſſed with great force from the ambient air, is really in the ſame caſe as if it was affected by no preſſure of the air at all. Now in order to obviate this by experiment ; when a flat bottle is empty and laid on its ſide, one would think that the weight of the

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* The particles of air are ſuppoſed by ſome to reſemble wool, but according to others like watch ſprings coiled up round, or wound up like pieces of ribbons.

air which falls on the external ſurface ſhould break it all to pieces ; but the air which is contained within the bottle, whether ſtopped or not, has the ſame power by its elaſticity to prevent its breaking as that without has to cruſh it to atoms. But if you apply a ſyringe to the neck of the bottle, and exhauſt that air which is encloſed within, the extraction of that ſmall body of air, which, by its elaſtic ſpring, ſupported the ſides of it, gives room to the external air to act on the ſurface of the bottle with all its force, and the bottle will fly into a thouſand pieces. I grant the ſame experiment will not anſwer on a round bottle, becauſe its ſtructure is like a vaulted roof, and the preſſure of the air is equally diffuſed in all manner of directions.

That the preſſure of the air is equal whether it act perpendicularly or laterally, is evident to every tapſter ; for when a barrel is new tapped, it will run little or none till the vent-hole be opened ; the reaſon is, becauſe the ſtaves of the caſk will prevent the incumbent atmoſphere from preſſing on the liquor within it, ſo that the preſſure at the cock ſuſtains the weight, or rather the preſſure of the liquor within the caſk.

That the atmoſphere preſſes in all manner of directions is evinced by taking two hollow hemiſpheres, 4 inches diameter, and putting their brims together, then pump the air out of them, and they will require about 190 lb. to pull them aſunder ; and therefore the atmoſphere preſſes with the force of about 15 lb. upon every ſquare inch, ſometimes more, and at other times leſs; which is equal to the weight of a column of mercury whoſe baſe is one ſquare inch, which it ſuſtained as was obſerved before.

But there needs no greater proof of the air's preſſing in all directions than that of the round bottle, for had it preſſed more on one part than another, it would have fared no better than the flat-ſided bottle recited above.

The denſity of the air is always as the force that preſſes, and therefore the air towards the upper part of the atmoſphere being leſs preſſed, will expand itſelf, and thereby become thinner than that at the ſurface of the earth.

Dr Halley firſt found out and demonſtrated, that if the altitude of the air be taken in arithmetical proportion, the rarity of the air will be in geometrical proportion.

For inſtance,

At the alt. of	7	miles from the ſurface of the earth, the air is	4	times thinner than at the ſurface.
	14		16	
	21		64	
	28		256	
	35		1024	
	70		1048576	

Hence it will be eaſy to calculate, that a cubic inch of common air, at the altitude of 500 miles, would be ſo much rarified, that it would be as large as the orbit of Saturn ; and therefore the planets may move thro' the upper regions of the heavens for many thouſand years, without ſuffering any ſenſible Reſiſtance.

According to this rule for finding the rarity of the air at any height, there will remain ſome air to an infinite diſtance, and yet the rarity at the height of about 40 or 50 miles is ſo great, that what is above is inconſiderable: And therefore the height of the atmoſphere is generally reckoned about 45 miles, at which height it is juſt ſufficient to inflect or bend a ray of light out of its right-lined courſe, which is the leaſt effect it can produce, and therefore all beyond that height muſt be eſteemed an unreſiſting æther.

The third and moſt remarkable property of air is, that it is rarified or made to ſwell with heat, which may be proved by many experiments. When air is condenſed in a certain determinate degree, by the application of heat, it acquires a greater power of expanſion every way than it had before; that is, it is rarified, or becomes thinner: And on the contrary, by cold it is contracted into a ſmaller ſpace, and becomes denſer, as appears by thermometer; conſequently the height of the atmoſphere perpetually varies, being greateſt at noon, and leaſt at midnight. Its denſity is alſo greater in winter than ſummer, being always in a ratio compounded of the direct ratio of the heights of the mercury in the barometer, and the reciprocal ratio of the diviſions made to the degrees of the thermometer. Wind* is a neceſſary conſequence of this property of air, for when it is heated by the ſun or otherwiſe, it will ſwell and drive the adjacent air away, and ſo by various degrees of heat in different places there will ariſe various winds.

When air is very much heated, it will aſcend towards the upper part of the atmoſphere, and the adjacent air will ruſh in to ſupply its place, and therefore there will be a ſtream or current of air from all parts towards the place where the heat is. Hence we can eaſily account for the monſoons or trade winds, which about the equator conſtantly blows from eaſt to weſt; for when the ſun ſhines perpendicularly on any part of the earth, it will heat the air in that part very much, which will therefore riſe upward, and the adjacent air will ruſh in to fill up the vacuum, and conſequently cauſe a ſtream or current of air from all parts towards the ſun; but as the ſun, with reſpect to the earth, moves from eaſt to weſt, the common courſe of the air will be that way too, continually preſſing after the ſun; and therefore, at the equator where the ſun ſhines ſtrongly, there will be continual eaſterly wind†, but on the north ſide it will incline a little to the north, and on the ſouth ſide to the ſouth.

This general courſe of the wind about the equator is changed in ſeveral places, and upon ſeveral accounts, as, 1. The attraction of the moon on the meridian may reaſonably be ſuppoſed to raiſe or ſwell the air no leſs than that of water in tides. (Some have wondered that theſe æreal tides do not affect the mercury in the barometer; but we muſt conſider that as theſe particles are rendered lighter, a greater number of them is accumulated, until the deficiency of gravity be made up by the height of the column, and there is an equilibrium, and conſequently an equal preſſure upon the mercury as before; ſo that it cannot be affected by thoſe æreal tides.) 2. Certain exhalations that riſe out of the earth at certain times and from certain places, in earthquakes eſpecially, and from volcanos. 3. The fall of great quantities of rain, hail, or ſnow, cauſing thereby a ſudden condenſation or contraction of the air. 4. The ſudden melting of ſnow, &c. on the higher mountains cauſing the condenſation near them ſuddenly to ceaſe. 5. Burning ſands that often retain the the ſolar heat to a degree incredible to thoſe who have not felt it, cauſing a more than ordinary degree of rarefaction in the air contiguous to them. 6. The oppoſition of high mountains that reflect the winds and alter the line of their direction. 7. The declination of the ſun towards the north or ſouth, heating the air either in this or that part of the world; of this we have experience;—every ſpring we have generally cold breezes from the north to ſupply the place of the rarified air on the ſun's approach towards us.

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* The velocity of the wind is at the rate of 50 or 60 miles an hour in a great ſtorm, a common briſk wind about 15 miles, and ſome move not one mile an hour.

† Theſe winds are repreſented in our maps by darts.

To theſe particulars, or ſuch like, is owing, 1. The manifeſt irregularity and uncertainty of the winds in climates far diſtant from the equator, as in moſt parts of Europe. 2. Thoſe periodical winds which in the Indian ſea blow half a year one way, and the other half another. 3. Thoſe winds, which on the coaſt of Guiney, and on the weſtern coaſts of America, blow always from weſt to eaſt. 4. The ſea breezes, which in hot countries blow generally from the ſea to the land in the day-time, and the land breezes which blow in the night; and in ſhort all thoſe ſtorms, hurricanes, whirlwinds, and all the irregularities which happen at different times and places, muſt proceed from ſuch cauſes as thoſe before mentioned.

Wind may be produced artificially by filling a phial bottle with water, and a ſmall quantity of aqua fortis to make it acid, than a piece of chalk being put into the mixture, a fermentation will enſue, by which the particles of chalk will be ſeparated and turned into air; and if a bladder was tied to the mouth of the bottle, it would not only be filled with this air, but would burſt by the force of its ſpring. This may ſerve as a proof that the particles of bodies are converted into the common air that we breathe.

The air in ſome caſes, tho' very rarely, is ſubject to the ſight, or may be perceived by the eye, thus, when you are placed upon an eminence, or riſing ground, in ſome open parts of the country, in a ſituation nearly facing the ſun, on a hot ſummer day, then if there be a gentle wind, or motion of the air, it will be ſhewn by reflection of light from the body of air in the vale below, and you will as perfectly ſee the undulations or waves of air almoſt, as you may thoſe of water agitated by a gentle wind.

In viewing objects thro' a teleſcope which magnifies to a very great degree, as it ſhews the body of air ſo it renders the view of other objects more confuſed and indiſtinct, which demonſtrates the truth of the above relation.

All common air is impregnated with a certain vivifying ſpirit, or *pabulum vitæ*, which is neceſſary to continue the lives of animals; and this vivifying ſpirit in a gallon of air is ſufficient to feed one man the ſpace of one minute, and not much longer.

The vivifying ſpirit of air is deſtroyed by paſſing through the lungs of animals, as may be proved by many experiments. And hence it is that an animal dies when put under a receiver, tho' no air be taken from it. This vivifying ſpirit is alſo infuſed in water, ſince air pervades the interſtices of that medium, for fiſh die when they are excluded from freſh air, as in a pond that is cloſely frozen over.

In ſhort, the eggs of inſects and the ſeeds of plants give no ſigns of life when freſh air is excluded from them, tho' never ſo well aſſiſted with

o-other proper aliments, ſo that freſh air is abſolutely neceſſary for the production and preſervation of animals and vegetables.

Air becomes vitiated if it remains ſtagnant or be pent up, ſo that the external air have not free admiſſion to it, as in vaults, mines, holds of ſhips, &c. it loſes its vivifying quality, and therefore becomes pernicious. Alſo an aduſt or burnt air, or ſuch as has paſſed through the fire, loſes this vital quality.

Air is the medium of all ſound, for a bell ſtruck in an exhauſted receiver cannot be heard. It is the medium which diffuſes light, for were there no atmoſphere to refract the ſun's rays, all around the heavens would appear dark in the day-time as at night, and the ſun, moon, and ſtars, only would appear viſible. Laſtly, it is an univerſal menſtruum, which diſſolves all bodies in time, and reduces their ſubſtances to new forms, as iron into ruſt, copper into verdigreaſe, &c.

It is evident from the laws of hydroſtatics, that if any body ſpecifically lighter than a fluid, as water, be immerſed therein, it will, by the preſſure of that fluid, emerge out of it and float on its ſurface ; thus, if a ſolid inch of wood which is lighter than a cubic inch of water be caſt therein, it will by the reſiſtance of that fluid aſcend to the top, and part of it remain ſuſpended above the ſurface ; that which is beneath is equal to as much water as the whole floating body doth weigh. Hence any ſubſtance lighter than the common air muſt of conſequence aſcend up to that region which is of equal rarity with it, and there float and attract other homogeneal particles, and become heavier before it can deſcend again.

The learned Dr Halley remarked, that if an atom of water be expanded into a ſhell or bubble, whoſe diameter ſhall be ten times as great as before, ſuch an atom will be ſpecifically lighter than the air, and will riſe ſo long as that flatus or warm ſpirit, which firſt ſeparated it from the maſs of water, ſhall continue to diſtend it to the ſame degree : But then that warmth declining, and the air growing cooler, and withal ſpecifically lighter, theſe vapours will ſtop at a certain region of the air, or elſe deſcend. Hence it is an eaſy matter to account for the dew which falls when the ſun ſets : Since moiſture continually exhales during the ſun's ſtay above the horizon, towards the evening, as the ſolar heat withdraws, theſe new-raiſed particles begin to aſcend very ſlowly for want of ſufficient heat to raiſe them ; and as the air cools they begin to condenſe and preponderate it at a ſmall diſtance from the earth's ſurface, and ſo deſcend again in ſmall globules. But theſe particles which aſcend in the heat of the day are carried into the upper region of the air, where they float, till the wind or other cauſes drive them together, whereby they are formed into clouds, and ſo the watery parts uniting together in greater drops deſcend in rains.

Dr Halley was the only perſon who undertook to eſtimate the quantity of vapour raiſed in a day from the Mediterranean ſea by the ſun's heat. He eſtimated this ſea to be 40 degrees in length, and 4 in breadth, allowances being made for the places where it is broader by thoſe where it is narrower, then there will be 160 ſquare degrees ut leaſt, and every ſquare degree of 69 miles will evaporate 33 millions of tons, conſequently the whole Mediterranean muſt loſe in vapours, in the ſpace of 12 hours in a ſummer's day, at leaſt 5280 millions of tons*. And this great man was in-

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* Which is above 1600 times more water than runs down the River Thames in 24 hours time.

induced to believe that water is ſometimes licked up faſter by winds than it exhales by the heat of the ſun.

The foundation of this eſtimation is grounded on an experiment which this learned doctor made on a pan of water, in which he placed a thermometer, and under which he ſet a pan of live coals, by which means he brought the water to the ſame degree of heat which is obſerved to be that of our air in the hotteſt ſummers, the thermometer nicely ſhewing it. He then affixed the pan of water, with the thermometer in it, to one end of the beam of the ſcales, and exactly counterpoiſed it with the weight in the other ſcale: And by the application or removal of the pan of coals, he found it very eaſy to maintain the water in the ſame preciſe degree of heat. Doing thus, he found the weight of the water ſenſibly to decreaſe; and at the end of two hours he obſerved, that there wanted half an ounce Troy all but 7 grains, or 233 grains of water, which in that time had gone off in vapour, tho' one could hardly perceive it to ſmoke, and the water was not ſenſibly warm. This quantity in ſo ſhort a time ſeemed very conſiderable, being little leſs than 6 ounces in 24 hours, from ſo ſmall a ſurface as a circle of 8 inches diameter.

Having given you a rationale of the atmoſphere and aſcent of vapours*, I ſhall now proceed to the philoſophical prognoſtics of weather: 1ſt, Then a thick and dark ſky, laſting ſome time without either ſun or rain, always becomes firſt fair, then foul, i. e. it changes to a clear ſky before it turns to rain. This the Rev. Mr Clarke obſerved, who kept a regiſter of the weather for 30 years; ſince put into Mr Derham's hands by his grandſon, the learned Dr Samuel Clarke: He ſays he ſcarce ever knew it to fail, at leaſt when the wind was in any of the eaſterly points: But Mr Derham has obſerved the rule to hold good be the wind as it will; and the cauſe is obvious: The atmoſphere is replete with vapours, which, tho' ſufficient to reflect and intercept the ſun's rays from us, yet want denſity to deſcend; and while the vapours continue in the ſame ſtate, the weather will continue ſo too. Accordingly ſuch weather is generally attended with a moderate warmth, and with little or no wind to diſturb the vapours, and an heavy atmoſphere to ſuſtain them; the barometer being commonly high. But when the cold approaches, and by condenſing, drives the vapours into clouds or drops, then way is made for the ſun beams, till the ſame vapours begin by farther condenſation formed into rain, and fall down into drops.

2dly, A change in the weather is followed by a change in the wind; thus, the northerly and ſoutherly winds, commonly eſteemed the cauſes of cold and warm weather, are really the effects of the cold or warmth of the atmoſphere; of which Mr Derham aſſures us he has had ſo many confirmations, that he makes no doubt of it. Thus it is common to ſee a warm ſoutherly wind ſuddenly changed into the north, by the fall of ſnow or hail; or to ſee the wind in a cold froſty morning north, when the ſun has well warmed the earth and air, wheel towards the ſouth; and again turn northerly or eaſterly in the cool of the evening.

To theſe I ſhall add ſome obſervations of my own, which I ſeldom or never knew to fail. I have ſometimes ſeen a cloud or rather a fleece of va-

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* Moiſture is perceived to exhale from the earth by the dazzling light which affects our eyes in droughty weather, for it refracts the reflected rays of the objects we behold.

vapour, floating in the air: Some give it the title of Noah's ark, becauſe it appears broadeſt over our heads, and narrower towards the extremities, it ſomewhat reſembles a boat, from which, I ſuppoſe, it had its name. Altho' this vapour appears to the eye in this form, yet in fact it is not ſo, this appearance being only a deception of the ſight, for it is nearly of an equal breadth throughout, and only appears broadeſt where it is vertical; becauſe the more remote any object is, the ſmaller is the optic angle, or angle under which it is ſeen: Thus a long walk, betwixt two rows of trees parallel to each other, appears always broadeſt in that part where you are ſtanding. However, this ark (as it is called) is a great ſign of rain if it ſtands ſouth-weſt and north-eaſt, and changes from a pale to a darker colour. I ſeldom knew it miſs rain within 48 hours after this phænomenon, and have often obſerved clouds ſupplied with matter from appearances of this nature in rainy weather; but when theſe vapours are changed from their dark to a brighter colour, it is a ſign of fair weather, becauſe they begin to diſperſe; the air at the ſame time buoying up the clouds a little higher, they begin to break off and diſperſe alſo. Hence when the clouds are high it is a ſign of fair weather, but when low 'tis a ſign of rain.

Now in order to eſtimate the height of the clouds, and thereby enable you to judge of the ſtate of the weather, it would be proper to caſt your eye on ſome mountain which is often frequented with clouds and miſts; if a cloud reſt on the mountain, and the reſt hang hovering over the vale or country, much about the ſame height, appearing dark and heavy, it is a ſign of rain, becauſe of their deſcent; and one may often predict a ſhower by obſerving when the mountain has got on its cap. But here it is proper to remark, that when there is a ſign of rain it will immediately after break off in wind with little or no rain at all. Now this is oftentimes occaſioned by the fall of rains in other parts, as was intimated before, or from the heat of the earth, which increaſes the ſpring of the air; or laſtly, by an actual tranſmutation of vapour into air: Of this we have inſtances of clouds, and even miſts, which claſs themſelves in layers on the top of a mountain, and form what is commonly called a wind hem, or wind helm. I ſuppoſe it acquired theſe appelations from its reſemblance of a hem, or border, and property of directing the courſe of the wind; for whenever you ſee the clouds ranged in this order along the top of a mountain, it is a certain indication of wind blowing from that point.

But I ſhall here give you another rule to know on what point of the compaſs the wind lies, even in a calm air, and hence one may often predict its courſe the enſuing day.

It was obſerved that air is the medium of ſound, I ſhall now inform you how ſound is communicated to the ear. The air being agitated by the vibrations of the ſonorous* body, there ariſes a motion proportionable to the motion of a circular wave on the ſurface of ſtanding water, which reaching the *tympanum*, or drum of the ear, and acting thereon, excites in us the ſenſation of ſound; and it was alſo remarked, that the denſity of the air is greater in the night ſeaſon than in the day; and hence it comes to paſs that ſound is heard both farther and better when the ſun is abſent than at other times. If in an evening after the ſun is ſet, or in a morning before he riſes, you hearken to the ſound of the ſtreams of a river, you will preſently know what way the wind or current of air directs its courſe, for the ſtream which lays on that point from whence the wind blows, ſounds generally the loudeſt; and when two ſtreams roar at the ſame time by turns, it is a ſign that there are two winds blowing from different points of the compaſs.

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* Hang a nail on a thread, and apply it to the ſide of a bell; with any other piece of metal, ſtrike on the ſonorous body, and you may perceive the ſound acting on the nail, which will cauſe it to agitate, and demonſtrate the above relation.

This aſſertion will be obviated when we conſider that ſound travels further with the wind than againſt it, and is heard much louder one way than the other; and tho' the air be calm, yet there muſt be a tendency towards that point where the courſe of the wind is directed; and this is the only reaſon why one ſtream is heard more diſtinct than another; hence it follows, that ſtreams are very ſeldom heard when the current of air tends from your ſituation towards the river, tho' at the ſame time they are plainly heard at a much greater diſtance on the other ſide.

This rule of knowing the courſe of the wind may prove of ſingular ſervice to thoſe who reſide nigh a river, for on appearance of vapours, one may reaſonably conclude whether the wind will bring or diſperſe them.

Moſt vegetables expand their flowers and down in ſun-ſhine weather, and towards the evening and againſt rain cloſe them again; eſpecially at the beginning, when their ſeeds are tender and ſenſible. This is viſible enough in the down of dandelion, and other downs, and eminently in the flowers of pimpernal*, the opening and ſhutting of which Gerard obſerves, are the countryman's weather-wiſer, whereby he foretels the weather of the following day. The rule is, if the flowers be cloſe ſhut up, it betokens rain and foul weather; if they ſpread abroad, fair weather. The ſtalk of trefoil, Lord Bacon obſerves, ſwells againſt rain, and grows more upright: And the like may be obſerved, tho' not ſo ſenſibly in moſt other plants. He adds, that in ſtubble fields there is found a ſmall red flower, called by the country people, pimpernel, which opening in the morning is a ſure indication of a fine day.

That vegetables ſhould be affected by the ſame cauſes that affect the weather, is very conceivable, if we conſider them as ſo many hygrometers and thermometers, conſiſting of an infinite number of *tracheæ*, or air veſſels, by which they have an immediate communication with the air, and partake of its moiſture, heat, &c. Theſe *tracheæ* are very viſible in the leaf of ſcabioiſe, vine, &c.

There is a kind of ſtem or beard which adheres to the ſeed of muſk crainſbill, and ſhepherd's needle, they being both of one claſs; this beard is endowed with the property of twiſting and untwiſting itſelf, as the air becomes drier or moiſter, and makes one of the beſt hygrometers I know of: It will move three or four times round the ſame way. The Seeds may be glued to the center of a graduated circle, and it will ſhew you the dryneſs and moiſture of the air for a year or two.

The old or common prognoſtics, viz. heavineſs in our bodies, ſwallows flying low, birds dreſſing their feathers, &c. ought not to be entirely ſlighted as uſeleſs, ſince ſuch things are occaſioned by the levity of the air on the approach of rain; for naturaliſts have obſerved that birds are ſurfurniſhed with an oil-bag ſhaped like a nipple, the ſituation of which is at the extremity of their body. This nipple has ſeveral ſmall apertures, and being affected by this ſignal, they preſs this nipple with their bills, and ſqueezing out the oil, wherewith they dreſs their plumage, after which water only ſlides over them, and thus are they ſecured from the falling rains. As for ſwallows flying low, the flies which they purſue for food, cannot bear up their bodies ſo well as when the air is heavier.

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* A ſmall creeping plant, not much unlike chick-weed or hen-bit. It has a ſmall red flower on its top, and grows in the fields by the ſide of the river Eden.

Hence, when the preſſure of the atmoſphere is decreaſed, the mercury in the barometer will fall, the air will become thinner or lighter, and the clouds floating in the atmoſphere, will ruſh into that place, and therefore there will follow cloudy or rainy weather; but, whenever the preſſure of the atmoſphere on any part of the earth increaſes, the mercury in the barometer will riſe, becauſe the denſity of the air, in that part, will increaſe; and the clouds, floating in the atmoſphere, will be buoyed up to a greater height, and there will conſequently follow clear and ſerene weather: Thence the barometer came to be called the weather-glaſs, from its property of predicting the weather as was intimated before.

A damp or moiſt atmoſphere may ſometimes be known by its reflecting the ſun's beams in cloudy weather; and from objects, as mountains, &c. appearing higher than uſual, or laſtly, from the ſun or moon appearing larger on the horizon than ordinary. The reaſon is, the atmoſphere being more replete with vapours ſometimes than others, which renders the objects viewed through it much fainter than uſual; hence, we imagine them to be larger, becauſe we fancy them to be at a greater diſtance from us, at theſe times than at others: For innumerable objects of vaſtly different magnitudes, placed at proportional diſtances, may all appear under the ſame optic angle, and the rays croſſing each other in the * pupil of the eye, limit the ſize of the picture on the † retina: hence the pictures of all thoſe objects muſt conſequently be of the ſame magnitude. Now, if viſion depended on the picture only, then equal pictures upon the retina wou'd ſuggeſt ideas of equal magnitudes of the objects; and, if the ſmalleſt fly was ſo near that it could cover a diſtant mountain from it, the fly ought to appear to us to be equal to the mountain. But, with inconceivable quickneſs of thought, we have a faculty of eſtimating the ſize of objects, by the notion we form of their diſtances.

Hence it is eaſy to ſee how many fallacies in viſion ariſe; for, as we may often be miſtaken in our notion of diſtance, ſo every ſuch miſtake muſt produce a correſponding error in our idea of the magnitude of the object. For, in foggy weather, at firſt ſight, we generally imagine objects which are juſt at hand to be at a much greater diſtance, and conſequently take them to be much greater things than what they are: Thus, a ſmall houſe, juſt at hand, is taken for a great building at a diſtance; becauſe it appears ſo dull and ill defined, when ſeen through the miſt, that we refer it to a much greater diſtance than it is really at; and therefore, under the ſame angle, we judge it much bigger.

Any one may ſatisfy himſelf that the moon appears under no greater angle in the horizon than on the meridian, by taking a large ſheet of paper,

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* The pupil is that little black ſpot, in the middle of the eye, which is vulgarly called the ſight of the eye.

† The retina is only the fibres of the optic nerve expanded, ſo as to cover the bottom of the eye all over on the inſide immediately behind the vitreous humour.

paper, and rolling it up in the form of a tube of ſuch a width, that obſerving the moon through it when ſhe riſes, ſhe may, as it were, juſt fill the tube; then tie a thread round it to keep it of that ſize, and when the moon comes to the meridian, and appears much leſs to the eye, look at her again, through the ſame tube, and ſhe will fill it juſt as much if not [*] more than ſhe did, at her riſing. When the full moon is in perigeo, or, at her leaſt diſtance from the earth, ſhe is ſeen under a larger angle, and muſt therefore appear bigger than when ſhe is full at other times; and, if that part of the atmoſphere, where ſhe riſes, be more replete with vapours than uſual, ſhe appears ſo much the dimmer, and therefore, we fancy her ſtill the bigger, by referring her to an unuſual great diſtance, knowing that no objects which are very far diſtant can appear big, unleſs they be really ſo. Vide Ferguſon's aſtronomy, page 72.

A wet ſummer is generally a cold one, not only becauſe the clouds intercept the ſun's rays from us, but becauſe cold is the cauſe of condenſation and precipitation of vapours; hence it ſollows, that when the weather breaks, it is obſerved to rain firſt on mountains and cold places; whereas, in warmer ſoils, the heat of the earth affecting the air, prevents their deſcent till this property of the air be altered.

It would be proper to caſt an eye towards the luminaries in order to diſcover whether or no any vapour interpoſes, which will greatly enable you to judge of the ſtate of the weather: thus, it is ſometimes diſcovered in the ſun's troubled face, ſometimes in the obtuſeneſs of the moon's horns, and ſometimes in the dull appearance of the ſtars.

Some think the early aſcent of miſts a certain indication of rain, eſpecially if the air be replete with vapours.

If the ſky appears duſky about the change or full of the moon, the weather will probably change, becauſe of the æreal tides; but ſince they are of ſuch a fleeting nature, nothing certain can be predicted from them, tho' they muſt undoubtedly have great influence over the weather.

The philoſophers are by no means agreed about the cauſe of freezing.

The Carteſians account for it, by the receſs, or going out, of the ethereal matter from the pores of the water. The Corpuſcularians, on the other hand, attribute it to the ingreſs of frigorific particles, as they call them; and this, they ſay, is a kind of niterous ſalt, which is the cauſe of congelation, by inſinuating itſelf betwixt the particles of water, and fixing them together like nails, it ſeems very probable indeed, that cold and freezing do ariſe from ſome ſubſtance of a ſaline nature floating in the air, ſince all ſalts, and particularly nitrous ones, when mixed with ice and ſnow, greatly encreaſe their cold and bulk. Mr Boyle made ſeveral experiments with metaline veſſels, exceeding thick and ſtrong, which being filled with water, cloſe ſtopped, and expoſed to the cold, burſt by the expanſion of the frozen fluid within them: and trees have been frequently known to ſplit and cleave, ſo as to be ſeen through, and this with a noiſe like the exploſion of fire-arms; tho' metals are ſaid to contract with froſt, for an iron tube being expoſed to the air, in a froſty night, loſt two lines[†] of its length.

Snow is formed when the aqueous particles mix with the nitrous ones, they then ſhoot into chryſtals, and form the original parts of ſnow, the

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[*] The ſun and moon ſubtend a greater angle on the meridian than in the horizon, being nearer the earth in the former caſe than in the latter.

[†] A line is the 12th part of an inch.

many parts thereof are of a regular figure for the moſt part, being as it were ſo many little rowels or ſtars of 6 points, being perfect and tranſparent ice, as one may ſee upon a pool or veſſel of water, upon each of which points are ſet other collateral points, and theſe always at the ſame angles or corners as are the main points themſelves. Theſe ſnowy cryſtals being of this hexagonal and ramous form, makes them apt to hitch into and hang upon one another till they make a body too heavy to be ſupported by the air, and then they deſcend in the form of flakes of ſnow.

An artificial ſnow may be thus produced: Warm a phial of aquafortis, and put therein ſome filings of pure ſilver; then ſet it in any place to cool, and the ſilver will deſcend to the bottom in flakes like a ſhower of ſnow, whoſe cryſtals viewed through the microſcope put on the ſame figure of the aqueous ſnow,and will continue ſo long as the weather remains cold.

The conſideration of hail may be diſpatched in a few words; for you are to conſider that it ſeldom or never hails but when the air is heavy, and vapours aſcend to a great height in it, which is moſtly the caſe in the ſpring of the year, when ſtorms of hail are much more frequent than in winter. In the higher regions of the air the cold is much more intenſe, and therefore it is preſumed a much greater quantity of nitre is to be found there; this cauſes a more immediate and ſtronger congelation of the aqueous particles, and binds them firmly into a body of ice of various magnitudes or ſizes, according to the degrees of cold. Theſe being conſiderably heavy deſcend from ſuch heights with great rapidity, in the form of a ſhower of hail.

Thunder proceeds from an hetrogenous commixture of the effluvia or exhalations of ſulphureous, nitrous and inflammable bodies in the air, which ferment and kindle into flames, and make horrible exploſions, like gun-powder, which we call thunder and lightning.

If you mix well together, 3 parts of common ſalt-petre, 2 parts of ſalt of tartar, and one of common brimſtone, all finely powdered, then half a dram, or a dram, of this mixtnre being put upon a fire ſhovel over a gentle fire, till it appear to melt and change colour gently, and in about a quarter of an hour it will go off with a report as great as fire arms, but can do no harm. This is called *pulvis fulminans*, becauſe it partly repreſents thunder.

I ſhall here ſhew a method to calculate the diſtance of clouds when you can ſee the fire, and hear the clap of thunder. Hang a ball up in a ſtring, let the length be 9 inches and 8-10ths betwixt the bottom of the ball and nail whereon it is ſuſpended, and it will vibrate $\frac{1}{2}$ ſeconds; hold this ball in your hand, and when you ſee the flaſh let it go; then count the vibrations or ſwings till you hear the clap of thunder; if you multiply this number by 571, the product will expreſs the number of feet the cloud is diſtant from you; for ſeveral experiments confirm that ſound moves uniformly at the rate of 1142 feet in a ſecond, conſequectly in half a ſecond it moves 571 feet.

The Aurora borealis, or northern lights, are what country people call ſtreamers, and are produced alſo from nitrous ſulphereous vapours, which are thinly ſpread through the atmoſphere, higher than the clouds, and by fermentation take fire, and the exploſion of one portion kindling the next, the flaſhes ſucceed one another till all the vapour within their reach is ſet on fire, the ſtreams whereof will converge towards the zenith of the ſpectator, or the point over our heads.

Take a large Florence flaſk, and put in a ſmall quantity of the oil of vitriol, with 4 times as much water, which will produce a conſiderable heat; then mix it with a few ſteel filings, which will produce an ebullation, and white vapour will ariſe; laſtly, apply a candle ſeveral times where it takes fire and circulates about, and it will appear like an Aurora borealis in miniature.

Ignis fatuus, or Will with a wiſp and Jack with a lanthorn, is ſuppoſed to be nothing but a fat, unctuous, and ſulpherous vapour, which being kindled in the air, reflects a kind of flame in the dark, and is wafted about by the air near the earth's ſurface, like a light in a lanthorn.

Such like vapours kindling in the ſerene air in the night, appear like falling ſtars, and are ſo called.

The rainbow, one of the fineſt phænomenon of nature, exiſts in the falling rain or dew, and is produced by reflection[*] and refraction[†] of the ſun's rays in the aqueous particles, which demonſtrates that colours are not inherent in the bodies which reflect the rays of light, but in the light itſelf. It was remarked in page 68, that the particles of light are infinitely ſmall; let us now conſider what bulk or magnitude a particle of light may be; one may eaſily judge betwixt the bodies of air and water, by the difference of their undulations; and as concuſſions of the air or ſounds are communicated many hundred times quicker than thoſe of water, therefore the particles of air muſt be ſeveral hundred times more ſubtile and active than thoſe of water. If then the light, as appears by experience, moves ſix hundred thouſand leagues almoſt in the ſame time that ſound does proceed two or three thouſand fathoms, the particles of light muſt be ſix hundred thouſand times more ſubtile and active than a particle[‡] of air which eſcapes our ſight, even thro' the beſt microſcope. This obliges us to lay aſide calculations, which in this caſe would prove very uncertain. Let us ſurvey the animalcula, which are hatched in the infuſion of a few grains of pepper in a little water; theſe little worms are often a thouſand times leſs than the ſmalleſt imperceptable mite. Since a good microſcope will diſcover them floating in a drop of water ſmaller than the leaſt grain of ſand; how ſmall muſt the particles be which compoſe their eye? How neat muſt thoſe images be that are painted at the bottom of this eye? Which images are compoſed at the extremities of an infinite number of the rays of light: What muſt a globule of light then be? And if each globule is compoſed of parts that endeavour to ſeparate from each other by a continual agitation (which loſing a little of their balance by a foreign force, communicate an impreſſion to the bottom of this animalcula's eye agreeable to its neceſſities) there muſt be an infinite diminution in the ſize of matter, an infinity of proportions in the moſt hidden motion, wonders in things that are inviſible as well as in thoſe that are ſeen.—— Hence it is evident that light is capable of being tranſmitted through any medium, whoſe pores are regular and unbroken,

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[*] Reflection is the caſting back the ſun's rays.

[†] Refraction is only bending or breaking the rays of light ſo as to turn them out of the direction in which they were moving, and make them move in another; thus, if you caſt a piece of metal into an empty veſſel, and then move backwards till you loſe ſight of it; if you cauſe another perſon to pour in water, by the refracted rays you will ſee it again.

[‡] This may at firſt ſight ſeem contradictory to my diſcourſe, p. 132, but it muſt be conſidered we can often ſee a body when we cannot perceive its conſtituent particles; thus, for inſtance, we can ſee the water but cannot perceive the ſize of its minuteſt particles which conſtitute the maſs.

But to return, this bow never appears but where it rains in the ſunſhine: And it may be artificially made by ſpouting out water, which by breaking aloft ſhall ſcatter into drops, and fall like rain; for the ſun on thoſe drops certainly cauſes the bow to appear to an eye duly poſited to the artificial rain; and theſe colours are cauſed by the refrangibility of the rays of light.

This is evident from the priſm, which is a triangular piece of poliſhed glaſs, where red is leaſt refracted, orange next, yellow next, green next, blue next, purple next, and violet moſt of all. All bodies appear of that colour, whoſe rays they reflect moſt, as a body appears red which reflects moſt of the red making rays, and abſorbs the reſt; a blue or green body reflects the blue or green making rays; and ſo of the reſt: Hence black abſorbs all the rays, and reflects none; and whiteneſs proceeds from all the colours promiſcuouſly reflected.

The ſenſations of different colours ſeem to ariſe from hence, that ſeveral ſorts of rays do make vibrations of ſeveral ſizes, which according to their magnitudes, do excite the ſenſation of ſeveral colours, much after the ſame manner that the vibrations of the air, according to their ſeveral bigneſſes, do excite the ſenſations of different ſounds. See Newton's optics at the end.

Halos are thoſe circles which are ſeen ſometimes to encompaſs the ſun and moon, and are often variouſly coloured. They always appear in a rimy or froſty ſky, and proceed from the refraction only of the light in the hailſtones in the air; their diameter is generally about 45 or 46 degrees.

A mock ſun is only the ſun's image reflected from a watery cloud.

Miſts and fogs are only exhalations or vapours caſt off from the earth's ſurface or water, by a warmth either internal or external, which cauſes them to aſcend in greater proportion than common, and faſter than they can riſe through the atmoſphere; or elſe to the want of a ſufficient degree of heat in the atmoſphere to attenuate theſe vapours and encreaſe their elaſticity, and conſequently their rarity; through the want of theſe qualities they are kept in the lower part of the atmoſphere in large and opake particles, viſible themſelves to the eye, but obſtructing the viſion of other objects through them.

Now, in order to obviate this relation, one's breath in a cold morning may be plainly perceived, becauſe of the cold which condences the particles, and renders them viſible; whereas in the warmer air, the particles of one's breath become inviſible, becauſe the flatus, or warm ſpirit, has free liberty of expanding the including ſhell, which it rarifies to that degree that it inſenſibly flies off and mixes with the air. In like manner, after a foggy morning, the ſun being aſcended high enough to warm the atmoſphere with its beams, the miſt or fog has been by degrees diſſolved and diſpelled in the form of clouds, or at other times totally vaniſhed away. On the contrary in froſty weather, this miſt freezes, and ſo becomes the hoar or white froſt, becauſe it adheres to the trees, ſhrubs, and graſs; which differs from what is called the black froſt, becauſe that is not attended with a miſt or fog.

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APPENDIX.

AS ſeveral articles of importance have eſcaped my notice when I was compiling the work, which might have rendered it much more intelligible and compleat; yet I hope they will not be quite unacceptable to the reader if they ſhould be inſerted here.

In page 35, you have all the new, full, and quarter moons, to the year 1900. But becauſe the lunar cycle of 19 years ſometimes includes 5 leap years, and at other times only 4, that table will ſometimes vary a day in leap-years, after February: And it is impoſſible to have one more correct unleſs we extend it to 4 times 19, or 76 years; in which there are 19 leap-years without a remainder; but even then to have it of perpetual uſe, it muſt be adapted to the old ſtile, becauſe in every centurial year, not diviſible by 4, the regular courſe of leap-years is interrupted in the new, as will be the caſe in the year 1800. Therefore upon the regular old ſtile plan, Mr Ferguſon, in his excellent ſyſtem of aſtronomy, computed the following table of the mean times of all the new moons to the neareſt hour for 76 years, beginning with with the year of Chriſt 1724, and ending with the year 1800.

This table may be made perpetual, by deducting 6 hours from the time of new moon in any given year and month from 1724 to 1800, in order to have the mean time of new moon in any year and month 76 years afterwards; or deducting 12 hours for 152 years, 18 hours for 228 years, and 24 hours for 304 years; becauſe in that time the changes of the moon anticipate almoſt a complete natural day; and if the like number of hours be added for ſo many years paſt, we ſhall have the mean time of any new moon already elapſed.

Suppoſe, for example, the mean time of change was required for January 1802; deduct 76 years, and there remains 1726; againſt which, in the following table, for January, I find the time of new moon was on the 21ſt day, at 11 in the evening, from which take 6 hours, and there remains the 21ſt day at 5 in the evening for the mean time of change in January 1802. Or, if the time be required for May 1701, add 76 years, and it makes 1777, which I look for in the table, and againſt it, under May, I find the new moon in that year falls on the 25th day, at 9 in the evening; to which add 6 hours, and it gives the 26th day at 3 in the morning for the time of new moon in May 1701.

By this addition for time paſt, or ſubtraction for time to come, the table will not vary 24 hours from the truth in leſs than 14592 years. And if inſtead of 6 hours for every 76 years, we add or ſubtract only 5 hours, 52 minutes, it will not vary a day in ten millions of years.

Although this table is calculated for 76 years only, and according to the old ſtile, yet by means of two eaſy equations it may be made to anſwer as exactly to the new ſtile for any time to come. Thus, becauſe the year 1724 in this table is the firſt year of the cycle for which it is made,

A Table ſhewing the Times of all the mean Changes of the Mo

M ſignifies Morni

Years of the Cycle	A.D.	January		February		March		April		May	
		D.	H.	D.	H.	D.	H.	D.	H.	D.	H.
1	1724	14	5 A	13	5 M	13	6 A	12	7 M	11	8 A
2	1725	3	2 M	1	2 A	3	3 M	1	4 A	1 30	4 M 5 A
3	1726	21	11 A	20	11 M	21	12 A	20	1 A	20	1 M
4	1727	11	8 M	9	9 A	11	9 M	9	10 A	9	11 M
5	1728	30	6 M	28	7 A	29	7 M	27	8 A	27	8 M
6	1729	18	2 A	17	3 M	18	4 A	17	4 M	16	5 A
7	1730	7	11 A	6	0 A	8	1 M	6	1 A	6	2 M
8	1731	26	9 A	25	10 M	26	10 A	25	11 M	24	11 A
9	1732	16	5 M	14	6 A	15	7 M	13	8 A	13	8 M
10	1733	4	2 A	3	3 M	4	4 A	3	4 M	2	5 A
11	1734	23	0 A	22	1 M	23	1 A	22	2 M	21	2 A
12	1735	12	9 A	11	9 M	12	10 A	11	11 M	10	11 A
13	1736	2 31	5 M 6 A	—		1 30	7 M 8 A	29	9 M	28	9 A
14	1737	20	3 M	18	4 A	20	4 M	18	5 A	18	5 M
15	1738	9	11 M	7	12 A	9	1 A	8	1 M	7	2 A
16	1739	28	9 M	26	10 A	28	11 M	26	12 A	26	0 A
17	1740	17	6 A	16	7 M	16	8 A	15	9 M	14	9 A
18	1741	6	3 M	4	4 A	6	4 M	4	5 A	4	5 M
19	1742	24	12 A	23	1 A	25	2 M	23	3 A	23	3 M
20	1743	14	9 M	12	10 A	14	11 M	12	12 A	12	0 A
21	1744	3	6 A	2	7 M	2	8 A	1 30	9 M 9 A	30	10 M
22	1745	21	4 A	20	5 M	21	5 A	20	6 M	19	6 A
23	1746	10	12 A	9	1 A	11	2 M	9	3 A	9	3 M
24	1747	29	10 A	28	11 M	29	11 A	28	0 A	27	12 A
25	1748	19	6 M	17	7 A	18	8 M	16	9 A	16	9 M
26	1749	7	3 A	6	4 M	7	5 A	6	6 M	5	6 A
27	1750	26	1 A	25	2 M	26	3 A	25	4 M	24	4 A
28	1751	15	10 A	14	11 M	15	11 A	14	0 A	13	12 A
29	1752	5	6 M	3	7 A	4	8 M	2	9 A	2 31	9 M 10 A
30	1753	23	4 M	21	5 A	23	6 M	21	7 A	21	7 M
31	1754	12	1 A	11	2 M	12	3 A	11	4 M	10	4 A
32	1755	1 31	10 A 11 M	—		1 31	11 A 0 A	29	12 A	29	1 A
33	1756	20	7 A	19	8 M	19	9 A	18	9 M	17	10 A
34	1757	9	4 M	7	5 A	9	6 M	7	7 A	7	7 M
35	1758	28	2 M	26	3 A	28	3 M	26	4 A	26	4 M
36	1759	17	10 M	15	11 A	17	0 A	16	1 M	15	1 A
37	1760	6	7 A	5	8 M	5	9 A	4	10 M	3	10 A
38	1761	24	5 A	23	6 M	24	7 A	23	8 M	22	9 A
39	1762	14	2 M	12	3 A	14	3 M	12	4 A	12	4 M

be Moon to the neareſt Hour, through four lunar Periods, or 76 Years.
Morning, A Afternoon.

	June		July		Auguſt		Sept.		Oct.		Nov.		Dec.	
I.	D.	H.	D.	H.	D.	H.	D.	H.	D.	H.	D.	H.	D.	H.
A	10	8M	9	9A	8	10M	6	10A	6	11M	4	12A	4	1A
M A	29	6M	28	7A	27	8M	25	8A	25	9M	23	10A	23	11M
M	18	2A	18	3M	16	4A	15	5M	14	5A	13	6M	12	7A
M	7	12A	7	0A	6	1M	4	1A	4	2M	2	3A	2 31	4M 5A
M	25	9A	25	10M	23	11A	22	11M	21	12A	20	1A	20	2M
A	15	6M	14	7A	12	7M	11	8A	11	9M	9	10A	9	11M
M	4	3A	4	3M	2	4A	2 30	5M 6A	30	7M	28	8A	28	9M
A	23	0A	23	1M	21	2A	20	2M	19	3A	18	4M	17	5A
M	11	9A	11	10M	9	11A	8	11M	7	12A	6	1A	6	2M
A	1 30	6M 7A	30	8M	28	8A	27	9M	26	10A	25	11M	24	11A
A	20	3M	19	4A	18	5M	16	5A	16	6M	14	7A	14	8M
A	9	0A	9	1M	7	2A	6	2M	5	3A	4	4M	3	5A
A	27	10M	26	11A	25	0A	23	12A	23	1A	22	2M	21	3A
M	16	6A	16	7M	14	8A	13	8M	12	9A	11	10M	10	11A
A	6	3M	5	4A	4	5M	2	5A	2 31	6M 7A	30	8M	29	8A
A	25	1M	24	2A	23	3M	21	3A	21	4M	19	5A	19	6M
A	13	10M	12	11A	11	0A	9	12A	9	1A	8	2M	7	3A
M	2	6A	2 31	7M 7A	30	8M	28	9A	28	10M	26	11A	26	11M
M	21	4A	21	5M	19	6A	18	6M	17	7A	16	8M	15	9A
A	11	1M	10	2A	9	3M	7	3A	7	4M	5	5A	5	6M
M	28	11A	28	0A	26	12A	25	1A	25	2M	23	3A	23	3M
A	18	7M	17	8A	16	8M	14	9A	14	10M	12	11A	12	0A
M	7	4A	7	5M	5	6A	4	6M	3	7A	2	8M	1 31	9A 10M
A	26	1A	26	2M	24	3A	23	3M	22	4A	21	5M	20	6A
M	14	10A	14	11M	12	12A	11	0A	11	1M	9	2A	9	3M
A	4	7M	3	8A	2 31	9M 9A	30	10M	29	11A	28	0A	27	12A
A	23	5M	22	6A	21	7M	19	7A	19	8M	17	9A	17	10M
A	12	1A	12	2M	10	3A	9	3M	8	4A	4	5M	6	6A
M A	30	11M	29	12A	28	0A	27	1M	26	2A	25	3M	24	3A
M	19	8A	19	9M	17	10A	16	10M	15	11A	14	0A	14	1M
A	9	5M	8	6A	7	7M	5	7A	5	8M	3	9A	3	10M
A	28	2M	27	3A	25	3M	24	4A	24	5M	22	6A	22	6M
A	16	11M	15	12A	14	1A	13	1M	12	2A	11	3M	10	4A
M	5	8A	5	9M	3	10A	2	10M	1 31	11A 0A	30	1M	29	1A
M	24	5A	24	6M	22	7A	21	7M	20	8A	19	9M	18	10A
A	14	2M	13	3A	12	2M	10	4A	10	5M	8	6A	8	7M
A	2	11M	1 31	12A 1A	30	1M	28	2A	28	3M	26	4A	26	4M
A	21	10M	20	10A	19	11M	11	11A	17	0A	16	1M	15	2A
M	10	5A	10	6M	8	7A	7	7M	6	8A	5	9M	4	10A

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The TABLE co

Years of the Cycle	A.D.	January	February	March	April	May	June
		D. H.	D. H.	D. H.	D. H.	D. H.	D. H.
40	1763	3 11 M	1 12 A	3 0 A	2 1 M	1 1 A 31 2 M	29 3 A
41	1764	22 8 M	20 9 A	21 10 M	19 11 A	19 11 M	17 12 A
42	1765	10 5 A	9 6 M	10 6 A	9 7 M	8 7 A	7 8 M
43	1766	29 2 A	28 3 M	29 4 A	28 5 M	27 5 A	26 6 M
44	1767	18 11 A	17 0 A	19 1 M	17 2 A	17 2 M	15 3 A
45	1768	8 8 M	6 9 A	7 10 M	5 11 A	5 11 M	3 12 A
46	1769	26 6 M	24 7 A	26 7 M	24 8 A	24 8 M	22 9 A
47	1770	15 2 A	14 3 M	15 4 A	14 5 M	13 5 A	12 4 M
48	1771	4 11 M	3 0 A	5 1 M	3 2 A	3 2 M	1 3 A
49	1772	23 9 A	22 10 M	22 10 A	21 11 M	20 11 A	19 0 A
50	1773	12 5 M	10 6 A	12 7 M	10 8 A	10 8 M	8 9 A
51	1774	1 2 A 31 3 M	———	1 4 A 31 5 M	29 5 A	29 6 M	27 7 A
52	1775	20 0 A	19 1 M	20 2 A	19 3 M	18 3 A	17 4 M
53	1776	9 9 A	8 10 M	8 10 A	7 11 M	6 12 A	5 0 A
54	1777	27 6 A	26 7 M	27 8 A	26 9 M	25 9 A	24 10 M
55	1778	17 3 M	15 4 A	17 5 M	15 6 A	15 6 M	13 7 A
56	1779	6 0 A	5 1 M	6 2 A	5 3 M	4 3 A	3 4 M
57	1780	25 10 M	23 11 A	24 11 M	22 12 A	22 0 A	21 1 M
58	1781	13 6 A	12 7 M	13 8 A	12 9 M	11 9 A	10 10 M
59	1782	3 3 M	1 4 A	3 5 M	1 6 A	1 6 M 30 7 A	29 8 M
60	1783	22 1 M	20 2 A	22 2 M	20 3 A	20 3 M	18 4 A
61	1784	11 9 M	9 10 A	10 11 M	8 12 A	8 0 A	7 1 M
62	1785	29 7 M	27 8 A	29 9 M	27 10 A	27 10 M	25 11 A
63	1786	18 4 A	17 5 M	18 5 A	17 6 M	16 6 A	15 7 M
64	1787	7 12 A	6 1 A	8 2 M	6 3 A	6 3 M	4 4 A
65	1788	26 10 A	25 11 M	25 12 A	24 1 A	24 1 M	22 2 A
66	1789	15 7 M	13 8 A	15 9 M	13 10 A	13 10 M	11 11 A
67	1790	4 4 A	3 5 M	4 5 A	3 6 M	2 6 A	1 7 M 30 8 A
68	1791	23 1 A	22 2 M	23 3 A	22 4 M	21 4 A	20 5 M
69	1792	12 10 A	11 11 M	11 12 A	10 1 A	10 1 M	8 2 A
70	1793	1 7 M 30 8 A	———	1 9 M 30 10 A	29 10 M	28 11 A	27 0 A
71	1794	20 5 M	18 6 A	20 6 M	18 7 A	18 7 M	16 8 A
72	1795	9 1 A	8 2 M	9 3 A	8 4 M	7 4 A	6 5 M
73	1796	28 11 M	26 12 A	27 0 A	26 1 M	25 1 A	24 2 M
74	1797	16 7 A	15 8 M	16 9 A	15 10 M	14 10 A	13 11 M
75	1798	6 4 M	4 5 A	6 6 M	4 7 A	4 7 M	2 8 A
76	1799	25 2 M	23 3 A	25 4 M	23 5 A	23 5 M	21 6 A
1	1800	14 11 A	12 12 A	13 0 A	12 1 M	11 1 A	10 2 M

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Note, The year 1800 b

continued.

ne	July		Auguſt		Sept.		Oct.		Nov.		Dec.	
H.	D.	H.	D.	H.	D.	H.	D.	H.	D.	H.	D.	H.
3 A	29	4 M	27	4 M	26	5 M	25	6 A	24	7 M	23	7 A
12 A	17	1 A	16	2 M	14	2 A	14	3 M	12	4 A	12	5 M
8 M	6	9 A	5	10 M	3	10 A	3	11 M	1	12 A	1 31	1 A 1 M
6 M	25	7 A	24	8 M	22	8 A	22	9 M	20	10 A	20	11 M
3 A	15	4 M	13	5 A	12	6 M	11	6 A	10	7 M	9	8 A
12 A	3	1 A	2 31	2 M 2 A	30	3 M	29	4 A	28	5 M	27	5 A
9 A	22	10 M	20	11 A	19	11 M	18	12 A	17	1 A	17	2 M
4 M	11	7 A	10	8 M	8	8 A	8	9 M	6	10 A	6	11 M
3 A	1 30	4 M 5 A	29	5 M	27	6 A	27	7 M	25	8 A	25	9 M
0 A	19	1 M	17	2 A	16	2 M	15	3 A	14	4 M	13	5 A
9 A	8	9 M	6	10 A	5	11 M	4	12 A	3	1 A	3	2 M
7 A	27	8 M	25	8 A	24	9 M	23	10 A	22	11 M	21	11 A
4 M	16	5 A	15	6 M	13	6 A	13	7 M	11	8 A	11	9 M
0 A	5	1 M	3	2 A	2	2 M	1 31	3 A 4 M	29	5 A	29	5 M
10 M	23	11 A	22	0 A	20	12 A	20	1 A	19	2 M	18	3 A
7 A	13	8 M	11	9 A	10	9 M	9	10 A	8	11 M	7	12 A
4 M	2	5 A	1 30	6 M 6 A	29	7 M	28	8 A	27	9 M	26	9 A
1 M	20	2 A	19	3 M	17	3 A	17	4 M	15	5 A	15	6 M
10 M	9	11 A	8	0 A	6	12 A	6	1 A	5	2 M	4	3 A
8 M	28	9 A	27	9 M	25	10 A	25	11 M	23	12 A	23	0 A
4 A	18	5 M	16	6 A	15	6 M	14	7 A	13	8 M	12	9 A
1 M	6	2 A	5	3 M	3	3 A	3	4 M	1	5 A	1 30	6 M 6 A
11 A	25	0 A	24	1 M	22	1 A	22	2 M	20	3 A	20	3 M
7 M	14	8 A	13	9 M	11	9 A	11	10 M	9	11 A	9	0 A
4 A	4	5 M	2	6 A	1 30	6 M 7 A	30	8 M	28	9 A	28	9 M
2 A	22	3 M	20	4 M	19	4 M	18	5 A	17	6 M	16	7 A
11 A	11	0 A	10	1 M	8	1 A	8	2 M	6	3 A	6	4 M
7 M 8 A	30	9 M	28	9 A	27	10 M	26	11 A	25	0 A	24	1 A
5 M	19	6 A	18	7 M	16	7 A	16	8 M	14	9 A	14	10 M
2 A	8	3 M	6	4 A	5	4 A	4	5 A	3	6 M	2	7 A
0 A	27	1 M	25	1 A	24	2 M	23	3 A	22	4 M	21	4 A
8 A	16	9 M	14	10 A	13	10 M	12	11 A	11	0 A	11	1 M
5 M	5	6 A	4	7 M	2	7 A	2 31	8 M 9 A	30	10 M	29	10 A
2 M	23	3 A	22	4 M	20	4 A	20	5 M	18	6 A	18	7 M
1 M	12	12 A	11	1 A	10	1 M	9	2 A	8	3 M	7	4 A
8 A	2 31	9 M 10 A	30	10 M	28	11 A	28	0 A	27	1 M	26	1 A
6 A	21	6 M	19	8 A	18	8 M	17	9 A	16	10 M	15	11 A
2 M	9	3 A	8	4 M	6	4 A	6	5 M	4	6 A	4	7 M

oo begins a new cycle.

made, if from any year of Chriſt aſter 1800 you ſubtract 1723, and divide the overplus by 76, the quotient ſhew how many entire cycles of 76 years are elapſed ſince the beginning of the cycle here provided for, and the remainder will ſhew the year of the current cycle, anſwering to the given year of Chriſt. Hence if the remainder be 0, you muſt inſtead thereof put 76, and leſſen the quotient by unity. Then look in the left hand column of the table forthe number in your remainder, and againſt it you will find the times of all the mean new moons in that year of the preſent cycle. And whereas in 76 Julian years, the moon anticipates 5 hours, 52 minutes; if therefore theſe 5 hours, 52 minutes be multiplied by the above found quotient, that is, by the number of cycles paſt, the product ſubtracted from the times in the table will leave the corrected times of the new moons to the old ſtile, which may be reduced to the old ſtile thus: Divide the number of entire hundreds in the given year of Chriſt by 4, multiply this quotient by 3; to the product add the remainder, from their ſum ſubtract 2; this laſt remainder denotes the number of days to be added to the times above corrected, in order to reduce them to the new ſtyle. The reaſon of this is, that every 400 years of the new ſtyle gains 3 days upon the old ſtyle; one of which it gains in each of the centurial years ſucceeding that which is exactly diviſible by 4 without a remainder; but then, when you have found the days ſo gained, 2 muſt be ſubtracted from their number on account of the rectifications made in the calendar by the council of Nice, and ſince by Pope Gregory. It muſt alſo be obſerved, that the additional days found as above directed, do not take place in the centurial years which are not multiples of 4 till February 29th, O. S. for on that day begins the difference between the ſtiles; till which day, therefore, thoſe that were added in the preceeding years muſt be uſed. The following example will make this accommodation plain.

Required the mean time of the new moon in June 1909, N. S.

From 1909 take 1723 years, and there remains 186, which divided by 76, gives the quotient 2, and the remainder 34.

d. h. m.
Then, againſt 34, in the table, is June 5 8 0 aſtern. and 5 hours, 52 min. multip. by 2, make to be ſubtr. 11 44

Remains the mean time, June 5 9 16 morning, according to the old ſtyle.

Entire hundreds in 1909 are 19, which divided by 4 quotes 4, and leaves a remainder of 3, which quotient multiplied by 3 makes 12, and the remainder added makes 15; from which ſubtract 2, and there remains 13, which number of days added to the above time, old ſtyle, gives June 18 day, 9 hour, 16 min. in the morning, new ſtile.

So the mean time of new moon in June 1909, new ſtyle, is the 18th day, at 16 minutes paſt 9 in the morning.

If 11 days be added to the time of any new moon in this table, it will give the time thereof, according to the new ſtyle, till the year 1800.—And if 14 days, 18 hours, 22 minutes, be added to the mean time of the new moon in either ſtyle, it will give the mean time of the next ſull moon, according to that ſtyle.

Altho' the time given in this table may ſometimes differ 10 or 12 hours from the true time, yet in moſt caſes it very nearly coincides with it, and may ſerve very well for common uſe. I might have given you a table of the true times of all the new moons in the Plinian period, but I intend to reſerve it for a ſecond volume (if this meets with encouragement) in which I intend, God willing, to preſent to the public, a neat ſet of aſtronomical tables, with precepts for uſing them, as plain and eaſy as any extant; whereby the true places of the ſun's and moon's apoge and node, may be exactly found, conſequently the changes of the moon, and eclipſes, may be calculated to the greateſt preciſeneſs; alſo Sir Iſaac Newton's lunar theory, with rules deduced from it and other theories, teaching how they are all conſtructed; with tables for finding at any time with great expedition, the places of planets and comets, together with the diſpoſitions of the fixed ſtars, their times of riſing, ſouthing, and ſetting, with other important articles to render the whole a compleat ſyſtem of aſtronomy.

The earth being farther removed from the ſun in ſummer than in winter (ſee p. 109) it may be aſked how it comes to paſs that ſince the ſun is the fountain of heat as well as light, our winters are much colder than our ſummers. In anſwer to this, it is be conſidered, that the ſun's rays fall with much leſs obliquity upon the ſurface of the earth on our ſide of the equator, in the ſummer, than in the winter; and, therefore, they not only act more forcibly upon it, but a greater quantity of them fall upon a given place. For it is ſhewn in mechanics, that a moving body, ſtriking perpendicularly on another, acts on it with all its force; and that a body ſtriking obliquely, acts with the leſs force the more it deviates from the perpendicular. Now fire, moving in right lines, is liable to the ſame mechanical law as other bodies, and conſequently its action muſt be meaſured by the angle of incidence; and hence, fire ſtriking on any obſtacle in a direction parallel thereto has no ſenſible effect, by reaſon the ratio is almoſt infinite, *i. e.* nothing: Hence, the ſun radiating on the earth, in the morning, ſcarce produces any warmth at all: Again, in the winter beſides that, the ſun is much lower in the heavens, when at his meridian height, than in ſummer; its rays paſs through a longer portion of the earth's atmoſphere, by which a great part are intercepted, and ſo make various refractions and reflections, turned another way; and laſtly, in ſummer, the ſun continues with us 16 hours, and is abſent about eight; whereas, in winter, it is with us but eight hours, and abſent 16; all which things conſpire to make a conſiderable alteration with reſpect to heat and cold. If this be ſo, why is not the weather hotter when the ſun is in the tropic of cancer, its rays falling with the leaſt obliquity, and paſſing the ſhorteſt way through the atmoſphere; and the days being the longeſt than it is about a month afterwards, when the ſun is in the next ſign? In anſwer to this, it is to be remarked, that bodies are not always hotteſt at the ſame inſtant the greateſt degree of heat is applied to them; they require time to heat as well as cool. It is the length of time, therefore, heat is applied to them as well as the degree of it, that determines the quantity of heat communicated to them. For the like reaſon, we find it warmer about two o'clock than at twelve, when the ſun is in its meridian altitude, and its rays fall thickeſt and moſt forcibly upon the earth.

Some proper Remarks on the Planets.

VENUS and Mercury I intimated in page 66, that their greateſt diſtances from the ſun were about 47° for Venus, and 20° for Mercury, which is a demonſtrative proof that their orbits lie within the earth's; for they never appear on the eaſt of our horizon when the ſun is on the weſt, and *vice verſa*: Hence Venus, of whom I ſhall take particular notice, when ſhe is weſt of the ſun in her orbit, ſhe becomes our morning ſtar; and when on the other ſide of her orbit is eaſt of him, ſhe is our evening ſtar, being each, by turns, for about 290 days; this may ſeem ſtrange, that Venus ſhould be longer on the eaſt or weſt ſide of the ſun than the time ſhe takes to perſorm her revolution round the ſun in nigh 225 days; but when we conſider, that the earth is going all the while round the Sun, with the obſerver upon it, the ſame way with, tho' not ſo quick as Venus, the wonder vaniſhes, becauſe the difference of the motions betwixt the earth and venus will be equal to the motion gone forward of the earth by venus, in 290 days, being about 179° of a revolution of venus with the earth, perſormed in no leſs than 584 days nearly; and hence we may form an idea of the cauſe why they ſometimes appear ſtationary, and of the retrogade motions of the planets, which is the only reſult of their different celerities, when compared with that of the earth. Vide 66th page in this book.

A Diſcourſe of the Ecliptic, Harveſt Moon, &c.

THE poſition of the moon's cuſps, or a right line touching the points of her horns, is very differently inclined to the horizon at different hours of the ſame days of her age, ſometimes ſhe ſtands as it were upright on her lower horn, and then ſuch a line is perpendicular to the horizon; when this happens ſhe is in what the aſtronomers call the nonageſimal degree, which is the higheſt point of the ecliptic above the horizon at that time, and is 90 degrees from both ſides of the horizon where it is then cut by the ecliptic; but this never happens when the moon is on the meridian, except when ſhe is at the very beginning of Cancer or Capricorn.

The inclination of that part of the ecliptic to the horizon in which the moon is at any time when horned, may be known by the poſition of her horns, for a right line touching their points is perpendicular to the ecliptic, and as the angle that the moon's orbit makes with the ecliptic can never raiſe her above, nor depreſs her below the ecliptic more than two minutes of a degree, as ſeen from the ſun, it can have no ſenſible effect upon the poſition of her horns. Therefore if a quadrant be held up ſo as one of its edges may ſeem to touch the moon's horns, the graduated ſide being kept towards the eye, and as far from the eye as it can be conveniently held, the arch which the plumb line and the edge of the quadrant, which ſeems to touch the moon's horns, will ſhew the inclination of that part of the ecliptic to the horizon; and the arch between the other edge of the quadrant and plumb line will ſhew the inclination of the moon's horns to the horizon at that time alſo.

It is obſervable that ♈ and ♎, ♋ and ♑, are points of the ecliptic diametrically oppoſite to each other, and the two latter are each at a quadrant's diſtance from the two former; hence it is evident, when Aries riſes, Libra ſets, and Capricorn, which is a quarter of a circle diſtant from each, will be upon the meridian; then the ecliptic will have the low elevation, and will only make an angle of 15° with the horizon in the latitude of London; but when Aries ſets, at which time Libra riſes in the eaſt, then will Cancer come upon the meridian, it being alſo a quarter of a circle diſtant from Aries and Libra, and then the ecliptic will have the higheſt elevation, making an angle of 62° with the aforeſaid horizon, therefore thoſe ſigns which riſe with the leaſt angles ſet with the greateſt, and *vice verſa*; when the moon is in thoſe ſigns which riſe or ſet with the leaſt angles, ſhe riſes or ſets with the leaſt difference of time, and with the greateſt difference in thoſe ſigns which riſe or ſet with the greateſt angles. From the riſing of Aries to the riſing of Libra (which is 12 ſiderial* hours) the angle increaſes; and from the riſing of Libra, it decreaſes in the ſame proportion. Hence it appears the ecliptic riſes faſteſt about *A*ries, and ſloweſt about Libra; conſequently in the ſpring when the ſun is in *A*ries, and the full moon in Libra, ſhe will riſe with the greateſt difference of time, and ſet with the leaſt, contrary to what ſhe will do when the ſun is in Libra and the full moon in Aries, for then ſhe will riſe with the leaſt difference of time and ſet with the greateſt; for ſhe will be ſo much later in ſetting each following night as ſhe was in riſing each following night in the ſpring; and ſhe will ſet each following night in the ſpring as ſoon as ſhe roſe in each following night in harveſt, which muſt of conſequence occaſion much more moon light in the time of harveſt than in the ſpring. See p. 47 of this book

As the ſigns taurus, gemini, cancer, leo, virgo, and libra, riſe ſucceſſively, the angle gradually increaſes which they make with the horizon, and conſequently muſt decreaſe in the ſame proportion as they ſet; and therefore the moon differs gradually more in the time of her riſing every day while ſhe is in theſe ſigns, and leſs in her ſetting; after which, thro' the other ſix ſigns ſcorpio, ſagittarius, capricornus, aquarius, piſces, and aries, the difference becomes leſs every day, until it be leaſt of all, viz. in piſces and aries.

On the parallel of London as much of the ecliptic riſes about piſces and aries in about two hours, as the moon goes through in ſix days; and therefore while the moon is in theſe ſigns, ſhe differs ſcarce 2 hours in riſing for ſix days together. But in about fourteen days afterwards the moon comes to virgo and libra, which are oppoſite ſigns to piſces and aries, and then ſhe differs about 4 times as much in riſing, viz. an hour and a quarter later every day than the former while ſhe is in theſe ſigns, for their riſing angle is at leaſt 4 times as great as piſces and aries.

In northern latitudes the autumnal full moons are in piſces and aries, and the vernal full moons in virgo and libra, in ſouthern latitudes juſt the reverſe, becauſe the ſeaſons are contrary; but virgo and libra riſe at as ſmall angles with the horizon in ſouthern latitudes, as piſces and aries do in the northern, and therefore the harveſt moons are juſt as regular on one ſide of the equator as on the other.

At the equator the north and ſouth poles lie in the horizon, and therefore the ecliptic makes the ſame angle ſouthward in the horizon when aries riſes as it does northward when libra riſes, conſequently the moon in all parts thereof riſes nearly at equal angles with the horizon all the year round, and about 48 minutes later every day or night than on the preceding, therefore there can be no particular harveſt moon at the equator.

The moon goes round the ecliptic in 27 days, 8 hours, and from change

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* The ecliptic, together with the fixed ſtars, make 366 and a quarter apparent diurnal revolutions about the earth in a year, the ſun only 365 and a quarter, therefore the ſtars gain 3 min. 56 ſec. upon the ſun every day; ſo that a ſiderial day contains 23 hours, 56 min. of mean ſolar time, and a natural or ſolar day 24 hours; hence 12 ſiderial are 1 min. 58 min. ſec. ſhorter than 12 ſolar.

to change in 29 days, 12 hours, ſo that ſhe is in piſces and aries at leaſt once in every lunation, and in ſome lunations twice.

If the earth had no annual motion, the ſun would never appear to ſhift his place in the ecliptic, and then every new moon would fall in the ſame ſign and degree of the ecliptic, and every full moon in the oppoſite; for the moon would go preciſely round the ecliptic, from change to change, ſo that if the moon was once full, in piſces or aries, ſhe would always be full when ſhe comes round to the ſame ſign and degree again; and as the full moon riſes at ſun ſet (becauſe when any point of the ecliptic ſets, the oppoſite point riſes) ſhe would conſtantly riſe within 2 hours of ſunſet, during the week, in which ſhe was at full. But in the time the moon goes round the ecliptic, from any conjunction or oppoſition, the earth goes almoſt a ſign forward; and therefore the ſun will ſeem to go as far forward in that time, namely 27½ degrees: So the moon muſt go 27½ degrees more than round; and as much farther as the ſun advances in that interval, which is 2$\frac{1}{15}$ degrees, before ſhe can be in conjunction or oppoſition to the ſun again. Hence it is evident that there can but be one conjunction or oppoſition in a year, in any particular part of the ecliptic. Something ſimilar to this, may be obſerved, in the hour and minute hands of a clock or watch, which are never in conjunction or oppoſition, in that part of the dial plate, where they were ſo laſt before.

As the moon can never be full but when ſhe is oppoſite to the ſun, and the ſun is never in virgo and libra, but in our autumnal months, it is plain that the moon is never full in the oppoſite ſigns, piſces and aries, but in theſe two months. And therefore we can have only two full moons in a year, which riſe ſo near the times of ſunſet for a week together, as the abovementioned. The former of which is called the Harveſt moon, and the latter, the Hunters moon. Now, ſince the moon is in piſces and aries at leaſt 12 times in a year, beſides, ſhe muſt then riſe with as little difference of time as in harveſt; but we muſt conſider, in winter, theſe ſigns riſe at noon, and being then only a quarter of a circle diſtant from the ſun, the moon in them is in her firſt quarter; and when the ſun is above the horizon, the moon's riſing is neither regarded nor perceived. In the ſpring theſe ſigns riſe with the ſun, becauſe he is in them: and as the moon changeth in them in that time of the year, ſhe is quite inviſible. In ſummer they riſe about midnight, and the ſun being then about 3 ſigns or a quarter of a circle before them, is in them in her third quarter, when riſing ſo late, and giving but little light, her riſing paſſes generally unobſerved. And in autumn theſe ſigns being oppoſite to the ſun, riſe when he ſets with the moon in oppoſition, or at full, which makes her riſing very conſpicuous.

The moon is never properly in the ecliptic but when ſhe is in either of her nodes, which is at leaſt twice in every courſe from change to change, and ſometimes thrice; for as the moon goes almoſt a whole ſign more than round her orbit, from change to change, if ſhe paſſes by either node about the time of change, ſhe will paſs by the other in about 14 days after, and come round to the former node again two days before the next change. That node from which the moon begins to aſcend northward, or above the ecliptic in northern latitudes, is called the aſcending node, and the other, the deſcending node, becauſe the moon when ſhe paſſes by it deſcends below the ecliptic ſouthward (ſee page 71). The moon's oblique motion, with regard to the ecliptic, cauſes ſome difference in the times of her riſing and ſetting, from what I have already mentioned. For when ſhe is northward of the ecliptic ſhe riſes ſooner, and ſets later, than if ſhe moved in the ecliptic; conſequently when ſhe is ſouthward of the ecliptic ſhe riſes later and ſets ſooner.

Now this difference is variable even in the ſame ſigns, becauſe the nodes ſhift backwards $19.^{\circ} : 21' : 20''\frac{3}{4}$ in the ecliptic every year; and ſo go round it in a retrograde or contrary order of the ſigns in * 18 years 218 or 219 days, when the aſcending node is in aries, the ſouthern half of the moon's orbit, makes an angle of about 5 degrees leſs with the horizon, than the ecliptic, when aries riſes in northern latitudes, for which reaſon the moon riſes with leſs difference of time whilſt ſhe is in piſces and aries, then there would be if ſhe kept in the ecliptic: But at the expiration of 9 years 109½ days, the deſcending node comes to aries, and then the moon's orbit makes an angle of about 5° greater with the horizon than the ecliptic does at that time, which muſt cauſe the moon to riſe with greater difference in piſces and aries, than if ſhe moved in the ecliptic. To explain this more fully when the aſcending node is in aries, the angle is only about 10 degrees on the parallel of London, when aries riſes; but when the deſcending node comes to aries, the angle is about 20 degrees. This occaſions as great a difference of the moon's riſing, in the ſame ſigns, every 9 years, on the parallel of London, as there would be on two parallels 10 degrees from one another, if the moon's courſe were in the ecliptic; ſince there is a complete revolution of the nodes in about 18¾ years, there muſt be a regular period of all the varieties that can happen in the riſing and ſetting of the moon during that time: But this ſhifting of the nodes never affects the moon's riſing, even in the quickeſt deſcending latitude, as not to allow us ſtill the benefit of her riſing, nearer the time of ſunſet for a few days together, about the full, in harveſt, than when ſhe is full at any other part of the year. Mr Ferguſon has undertaken to give us an account in what years the harveſt moon are moſt and leaſt beneficial to us, in regard to their riſing, from 1751 to 1861, a tranſcript of which you have below.

HARVEST MOONS affording the leſs Light.

	1751	1752	1753	1754	1755	1756	1757	1758	1759	
	1770	1771	1772	1773	1774	1775	1776	1777	1778	
N.	1788	1789	1790	1791	1792	1793	1794	1795	1796	1797
	1807	1803	1809	1810	1811	1812	1813	1814	1815	
	1826	1827	1828	1829	1830	1831	1832	1833	1834	
	1844	1845	1846	1847	1848	1849	1850	1851	1852	

Here the Moon, in Dates to the Left is in the greater N. *Lat. and deſcends to the greater* S. *Lat. in Dates to the Right.*

HARVEST MOONS affording the greater Light.

	1760	1761	1762	1763	1764	1765	1766	1767	1768	1769
	1779	1780	1781	1782	1783	1784	1785	1786	1787	
	1798	1799	1800	1801	1802	1803	1804	1805	1806	
S.	1816	1817	1818	1819	1820	1821	1822	1823	1824	1825
	1835	1836	1837	1838	1839	1840	1841	1842	1843	
	1853	1854	1855	1856	1857	1858	1859	1860	1861	

Here the Moon, in Dates to the Left is in the greater S. *Lat. and aſcends to the greater Lat.* N. *in Dates to the Right.*

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* Mr Ferguſon, differs from this account of Sir Iſaac Newton's, in the revolution of the moon's nodes, by about 6 days; he makes their revolution to be in 18 years 225 days; but which of them comes neareſt the truth, time itſelf muſt determine.

Now the rule given in page 38, will not give the true time of the riſing of the harveſt moons; therefore to know this, after her ſouthing is found, find out what ſign and degree ſhe is in, (by the rule in page 41) ſo that being found, and alſo what time the ſun is there, then obſerve the time of ſun ſetting when he is in that place (by rule p. 40) and that is half the continuance of the ſun or moon above the horizon, which being added to the time of the moon's ſouthing, ſheweth the time of her ſetting; and ſubtracted from it, ſheweth the time of her riſing, very near; but becauſe of her being ſometimes north, and ſometimes ſouth of the ecliptic, her true riſing will ſometimes differ a few minutes from what you find by this rule; yet this is as exact a method as any, except we find her riſing, ſouthing, and ſetting, from aſtronomical tables.

This diſcourſe of the harveſt moon, leads me to another of equal importance, wherein we ought juſtly to admire the profound wiſdom of our Divine Creator. At the poles, the equator is in their horizon, conſequently, one half of the ecliptic never riſes, and the other half never ſets. Hence the ſun will be half a year in deſcribing ½ the ecliptic, and as long in deſcribing the other half, we ſhould be apt to think that the ſun continues half a year together, above the horizon of each pole, in its turn, and as long below it; riſing to one pole, when it ſets to the other; this would be exactly the caſe, if there were no refraction; but by the atmoſphere's refracting the ſun's rays, he becomes viſible ſome days ſooner, and continues ſome days longer in ſight, than he would otherwiſe do: So that he appears above the horizon of either pole, before he has got below the horizon of the other; and as he never goes more than 23½ below the horizon of the poles, they have very little dark night, it being twilight, as well as all other places, till the ſun be 18 degrees below the horizon. The full moon being always oppoſite to the ſun, can never be ſeen while the ſun is above the horizon; except when the moon falls in the northern half of her orbit; for when ever any point of the ecliptic riſes, the oppoſite point ſets. Therefore as the ſun is above the horizon of the north pole, from the 20th of March to the 23d of September it is plain, that the moon when full, being oppoſite to the ſun, muſt be below the horizon during that half year; but when the ſun is in the ſouthern half of the ecliptic, he never riſes to the north pole, during which half year, every full moon happens in ſome part of the northern-half of the ecliptic, which never ſets; conſequently as the polar inhabitants never ſee the full moon in ſummer, they have her always in winter, before, at, and after the full, ſhining for 14 of our days and nights; and when the ſun is at his greateſt depreſſion, below the horizon, being then in capricorn, the moon is at her firſt quarter in aries, full in cancer, and third quarter in libra; and as the beginning of aries, is the riſing point of the ecliptic, cancer is the higheſt, and libra the ſetting point. The moon riſes at her firſt quarter in aries, is moſt elevated and full in cancer, and ſets at the beginning of libra in her third quarter, having continued viſible for 14 diurnal rotations of the earth. Thus they are ſupplied half of the winter ſeaſon with conſtant moon light, in the ſun's abſence, and only loſe ſight of the moon from her third to her firſt quarter, while ſhe ſhews very little light and would be little, and ſometimes of no ſervice to them.

In page 109 the annual revolutions of the earth are ſaid to be all equal, and performed in 365 days, 5 hours, and 49 minutes nearly; but this is to be underſtood of mean time, and not of the true; for the true time will ſometimes be more, and ſometimes leſs, by about 6 or 7 minutes, which is occaſioned by diſturbances in the ſyſtem, when the planets are in the ſame quarter of the heavens; for they mutually gravitate one towards another, and thereby diſturb each others motions.

A

A TABLE *of the Sun's Declination in every Degree of the* ECLIPTIC.

Degrees	♈	♎		♉	♏		♊	♐		
	0	6		1	7		2	8		
	Nor.	Sou.		Nor.	Sou.		Nor.	Sou.		
	D.	M.	S.	D.	M.	S.	D.	M.	S.	
0	0	0	0	11	29	33	20	11	16	30
1	0	23	54	11	50	35	20	23	49	29
2	0	47	48	12	11	26	20	36	0	28
3	1	11	42	12	32	5	20	47	48	27
4	1	35	34	12	52	31	20	59	13	26
5	1	59	25	13	12	44	21	10	15	25
6	2	23	14	13	32	54	21	20	53	24
7	2	47	1	13	52	32	21	31	7	23
8	3	10	45	14	12	5	21	40	58	22
9	3	34	26	14	31	24	21	50	24	21
10	3	58	4	14	50	28	21	59	25	20
11	4	21	38	15	9	17	22	8	2	19
12	4	45	8	15	27	51	22	16	14	18
13	5	8	34	15	46	9	22	24	0	17
14	5	31	55	16	4	11	22	31	21	16
15	5	55	11	16	21	57	22	38	16	15
16	6	18	21	16	39	26	22	44	45	14
17	6	41	25	16	56	37	22	50	49	13
18	7	4	23	17	13	31	22	56	26	12
19	7	27	15	17	30	7	23	1	36	11
20	7	50	0	17	46	15	23	6	20	10
21	8	12	36	18	2	24	23	10	38	9
22	8	35	5	18	18	3	23	14	29	8
23	8	57	26	18	33	24	23	17	52	7
24	9	19	39	18	48	25	23	20	49	6
25	9	41	43	19	3	5	23	23	19	5
26	10	3	37	19	17	26	23	25	22	4
27	10	25	21	19	31	25	23	26	57	3
28	10	46	56	19	45	3	23	28	5	2
29	11	8	20	19	58	20	23	28	46	1
30	11	29	33	20	11	16	23	29	0	0
	♓	♍		♒	♌		♑	♋		
	11	5		10	4		9	3		
	Sou.	Nor.		Sou.	Nor.		Sou.	Nor.		

The Uſe of this TABLE.

HAving found by rule, page the 40, what ſign and degree, the ſun is in, enter this table, and if the ſign be at the head, the degrees thereto belonging are in the left-hand column; but if the ſign be at the foot, the degrees are on the right-hand; both which being found, the common angle of meeting, ſhews the ſun's declination at that time. Example, what is the declination on the 15th of May, the ſun's place being 24^{c}, in ♉? Look under ♉, and againſt 24, on the right-hand, is is 18° : 48′ : 25″, for the ſun's declination that day; that is, he is 18° : 48′ : 25″ north of the equator.

Note, This is uſeful in finding the latitude. See rule (page 79.)

If the linea apſidum, or line of apſides, (ſee p. 108) *together with the equinoctial and ſolſticial points, were immoveable, the table of the equation of time, p.* 101, *would always keep true; but with reſpect to the fixed ſtars, the line of apſides, moves forward* 12″, *every year, and the above points,* 50 *ſeconds backwards: So that if in any given year, the equnoctial points and line of apſides, were coincident in* 100 *years afterwards, they would be ſeparated* 1 *d.* 43′ 20″, *and could not meet again, ſo that the ſame equinoctial point ſhould fall again into the apogee, in leſs than* 20,903; *and this is the ſhorteſt period in which the equation of time can be reſtored to the ſame ſtate again, in reſpect to the ſame ſeaſons of the year.*

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Containing ſeveral important articles to illuſtrate the whole.

ERRATA.

Note, *When* b *is placed to the number of the line, that line is counted from the foot or bottom of the page, all the reſt are reckoned from the top.*

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The reader is deſired to correct according to the above directions, for humanum eſt errare.

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